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STUDY OF OPEN-AIR THERMIONIC RADIO DETECTER

by

BROOKS LAWSON CONLEY

A Thesis Submitted for the Degree of
BACHELOR OF SCIENCE
Electrical Engineering Course

UNIVERSITY OF WISCONSIN

1918

TABLE OF CONTENTS.

	Page.
Introduction	1
Chapter I. The Vacuum Bulb.	4
Chapter II. The Open-air Thermionic Detecter.	16
Chapter III. Methods and Results.	19
Conclusions.	

INTRODUCTION.

The open-air thermionic or tri-electrode radio detecter consists of a grid which is interposed in a gaseous medium, as air, between a plate P and an incandescent filament F. When these three electrodes are connected in the circuit shown in Fig.1, a current flows from the plate to the filament through the gas between the plate and filament. The magnitude of this "plate" current, and consequently the power supply from the plate battery E_p, is controlled by the potential of the grid relative to the filament.

The relations are such that a small power supply to the grid circuit is sufficient to control a large power delivery from the plate battery. The detecter is thus an amplifying device.

The fundamental difference between the open-air thermionic detecter and the well known "audion" or vacuum tube thermionic detecter is that in the former the three electrodes are mounted in the air, and in the latter they are mounted in an evacuated glass bulb or tube.

The history of the origin of the open-air thermionic detecter is of interest. In the early development of the Nernst Lamp, one of the troublesome difficulties to be overcome was the damage to the automatic heating device resulting from a small thermionic current which passed (leaked) through the air from the incandescent glower to the adjacent surface of the heating device. This experience with thermionic currents through the air led Edward

Bennett, one of the engineers instrumental in overcoming this particular difficulty in the development of the Nernst Lamp, to suspect that it might be possible to develop tri-electrode thermionic amplifiers and oscillators with the electrodes mounted, -not in a vacuum,- but in the open air.

The inventor was able to confirm this notion during the summer of 1917 by constructing a tri-electrode oscillator having a Nernst glower as the incandescent filament. This oscillator gave sustained oscillations of audio frequencies.

During the fall of the same year, sustained oscillations of radio frequencies were obtained. The device was also used as a detecter to detect the presence of sustained radio frequencies by the heterodyne or beat principle, and in receiving time signals from Arlington, Va., although in the time signal tests, the detecter gave, not the desirable "flute" note, but a "mush" note similar to the note obtained from an audion which is improperly adjusted.

The experimental investigations of the open-air tri-electrode device have pertained mainly to its possibilities as a generator of sustained oscillations. The purpose of this thesis is to continue the experimental work on the open-air device with the object of determining the conditions and adjustments necessary to the best performance as a detecter. This work involves the taking of some additional data for other characteristic curves, taking oscilligrams, determining the circuit constants, and receiving signals from distant stations. A study of the characteristic

curves must be made in order to determine the conditions under which the best results are to be expected.

On account of the great similarity between the theory of the audion and the open-air detecter, a thorough understanding of the audion is necessary in order to make an intelligent study of the open-air detecter. For this reason, considerable matter on the theory of the audion is introduced at the beginning, together with some characteristic curves of an audion plotted from data taken in the laboratory. This is done in order that the open-air detecter may be compared with the audion, and the differences made clear.

The experimental work was done by the writer and Mr. R.H.Jones under the direction of Professor Edward Bennett.

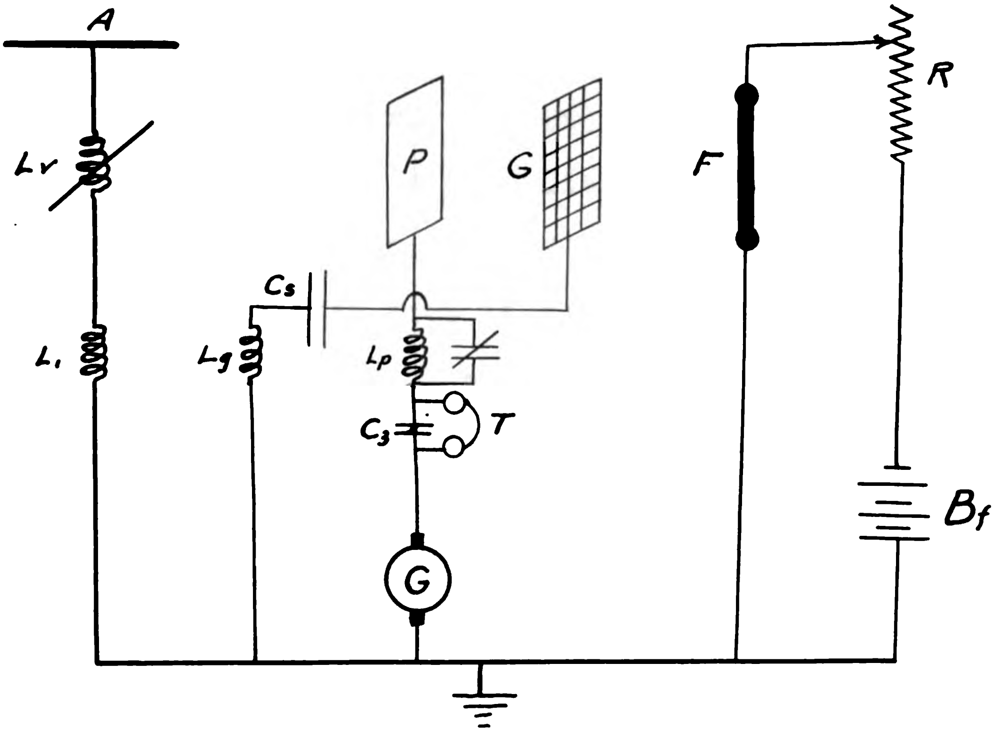


Fig. 1.

CHAPTER I.

THE VACUUM BULB.

The three-element vacuum bulb is by far the most important device for the reception of radio signals. It surpasses all other detecters, and has so many advantages that is is coming into almost universal use.

An intelligent study of the vacuum bulb can best be made by making a study of the electric circuits involved, and the factors that effect these circuits.

In studying and analyzing an electric circuit, it is necessary to consider the carriers of electricity. There are two principal carriers of electricity, viz., the ion and the electron. An electron is the smallest carrier of electricity, and is usually considered as the negative charge itself. The electron is smaller than the atom, in fact, atoms are composed of electrons. Ions are made up of one or more atoms, and are usually formed by dissociating the atoms of a molecule. Molecules can be dissociated into ions, ions into atoms, and an atom may have one or more electrons dissociated from it. An atom is neutral, that is, it has neither a positive or negative charge. An electron has (or is) a negative charge. When an atom loses one or more electrons, it becomes positive.

In ordinary electrical work, the electrical circuit is made up wholly of some conducting substance,the metals being the most common, but often containing some non-metal such as carbon. In radio circuits we often have to deal with circuits, some part of which is gaseous media, or even a vacuum. In such circuits, the

problem of conduction is more complicated than in the metallic circuit. But the problem is attacked in about the same way, that is, we wish to study the relation between e.m.f. and current, the impedance of the circuit, and the conditions under variation of temperature,etc. In order to do this, it is necessary to consider the various ways by which electricity is conducted. In circuits containing a gaseous medium, there are three ways of conducting electricity, (1) conduction by the passage of electrons from the cathode to anode, (2) conduction by th passage of positive ions from anode to cathode, (3) and a combination of the two by a flow of both ions and electrons.

In a vacuum,there is only one method of conduction, and that by means of pure electron flow. In practice,it is impossible to obtain a perfect vacuum, but it can be so closely approached, that conduction occurs by means of pure electron flow.

In our work, the pure electron flow is the most important. In the vacuum bulb, conduction takes place wholly by pure electron flow, and in the open-air detecter, pure electron flow is of most importance, but there must be some ionization by collision, as there always is when a gas is present in appreciable quantity.

This chapter deals with the vacuum bulb, hence it is necessary to consider only one form of conduction, viz., conduction by pure electron flow.

The vacuum bulb as used in modern radio telegraphy and telephony, consists of a highly evacuated bulb, usually about the size of a small incandescent lamp. The quantity of air that the bulb contains is so small that conduction takes place by means of pure electron flow only. The bulb contains three elements,the

filament,plate and grid. The general appearance of the bulb is similar to that of an incandescent lamp, although the glass bulb if often of slightly different shape. The method of manufacture is about the same as that of an incandescent lamp. The method of sealing,making the stem, and sealing the leading-in wires, is almost identical with that of an incandescent lamp. The filament is made of tungsten of about the same quality as lamp filament.

The plate is usually made of metal, although graphite or other non-metal is sometimes used. In the best known types of bulbs, the plate is of nickel plated metal. It sometimes consists of two metal plates connected together, one on each side of the filament, and about 1" x ½" in the common sized bulb, but varying with the size of the bulb. In some types of bulbs, the plate is in the form of a cylinder surrounding the filament.

The third element, the grid, usually consists of a rectangular section of meshed wire, although in some bulbs it is merely a wire bent into the form of a helix. The grid is placed between the plate and filament. With this arrangement, the bulb has four terminals, the two filament terminals, the plate terminal and the grid terminal. In operating the bulb, it is necessary to have the filament hot, because only a hot body can emit electrons under ordinary conditions. The filament is made incandescent by passing an electric current through it. The current used to keep the filament hot, has nothing further to do with the action of the bulb or the circuit connected with it, and might be dispensed with if there were some other means of keeping the filament hot.

In order to explain the action of the bulb, only filament and plate will be considered first. The bulb may be considered to consist of only two elements,the filament and plate, or what is the same thing, the grid may be neglected and its terminal left free and not connected in any way to the circuit, and the action of the bulb studied when the grid is inactive. Fig.2 shows the set-up for obtaining the plate-filament characteristic. Here is a complete metallic circuit with the exception of the gap between plate and filament. If the filament is cold, no current will flow unless enough voltage is applied to cause a spark to jump across the gap, and this will require several thousand volts. In a metallic circuit, current flows according to Ohm's Law, and the electrons are much freer than in any other circuit. It takes comparative little e.m.f. to move the electrons, i.e., the metal offers an easy path for the electrons, and we say that the resistance is low. But if there is a rupture in the circuit, no current flows because the electrons are held at the end of the metal circuit, and are not set free. If they were set free from the metallic part of the circuit, they would immediately cross the gap and continue circulating around the circuit. The potential between the plate and filament is equal to the e.m.f. of the battery B, and if electrons were set free at the filament, the electric field due to the potential between plate and filament will fur-

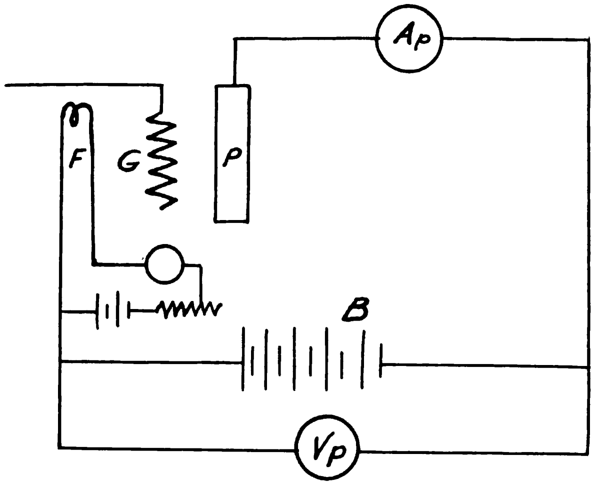


Fig. 2.

nish a force that will carry the electrons across the gap and current will flow in the circuit. If some condition is introduced which will free these electrons at the cathode, i.e., the filament, the electrons will cross the gap and current will flow in the circuit. It has been found that electrons are set free from a surface which has been heated, the number set free being a function of the temperature. The filament of the audion is heated by sending a current through it. The battery A furnishes this current.

Having a circuit as shown in Fig.2, it is desired to know the characteristics of the circuit, i.e., how the current depends upon the voltage between plate and filament. This characteristic is obtained by taking readings of the ammeter A_p and the voltmeter V_p as the voltage of the battery B is varied, and plotting the result as shown in Fig.3, which shows the shape of the characteristic curve for this circuit. It is seen that Ohm's Law does not hold for this circuit, for the graph of Ohm's Law is a straight line. As the voltage increases, the current increases nearly as the 3/2 power of the voltage until a point "a" is reached, where the rate of current increase begins to decrease. Finally a point is reached where the characteristic becomes a horizontal line, there being

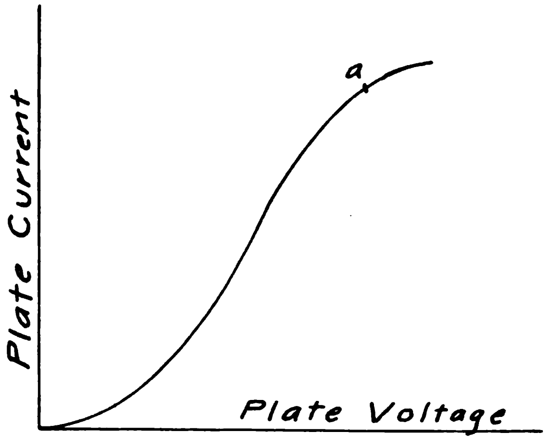
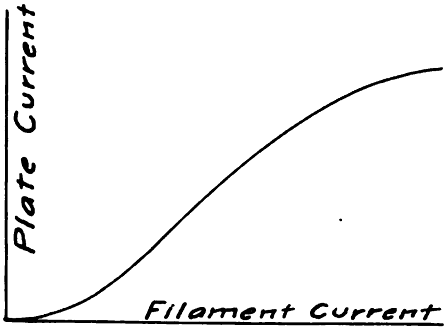


Fig. 3.

no increase in current for increases in voltage. This may seem rather strange, but according to present accepted theory, a certain filament temperature liberates a certain number of electrons, and the flow of this maximum number of electrons represents the maximum current that can flow for that definite temperature. Hence,no matter how great the plate potential may be, no more electrons can flow across the gap than are liberated at the filament. The temperature of the filament is proportional to the square of the current, and it is convenient to plot current against voltage. If more plate current is wanted than is represented by the horizontal part of the curve, the filament temperature must be increased, and this is done by increasing the filament current. When the filament current is increased, the point "a" at the upper bend of the curve will be higher,and represents more plate current.

This result gives rise to a desire for another characteristic curve, one showing the relation between the filament current and plate current for a constant value of plate voltage. This is easily obtained by taking readings of plate current and filament current as the filament current is varied and the plate voltage held constant, and plotting the result as shown in Fig.4. The shape of this characteristic is about the same as the preceeding one. Here,also, a point is reached where further increase in filament current causes no

Fig.4



increase in plate current. It would seem at first thought that there should be no limit to the plate current as the filament current is increased. There is no friction encountered by the electrons in their path between filament and plate. When the plate voltage is kept constant and the filament temperature increased, thus increasing the number of electrons liberated per second, the plate current also increases up to a certain value, but remains constant for further increases of temperature. This phenomenonis caused by the space charge, which is a negative charge in the space between the filament and plate due to the negative charges of the cloud of electrons in that space. This negative space charge neutralizes the field due to the positive plate. Therefore, only a certain number of electrons can flow from the filament to the plate with a given plate voltage. If more than this number of electrons leave the plate, the electric intensity of field due to the space charge is greater than the electric intensity of field due to the positive plate, the result being a reversed field, and enough electrons must return to the filament to make the electric intensity of field due to the space charge less than the electric intensity of field due to the positive plate. A state of equlibrium exists between the space charge and the field due to the positive plate, which allows a definite number of electrons to flow per second.

The action of the grid will now be considered. The relation between filament current, plate current, and plate voltage is now known, and it remains to be seen what the modifying effect of the

grid is. To make this determination, the same circuit is used as before except that the grid circuit is completed, and grid, battery C, filament, connecting wires, and the gap between grid and filament make a complete circuit. It is now to be seen what the effect of this grid circuit is on the plate circuit. By varying the voltage of the battery C, a varying potential is produced between grid and filament in the same manner that there is a difference of potential between plate and filament produced by the battery B. Evidently the introduction of this potential will modify the current in the plate circuit. To find out what this effect is, the plate voltage and filament current are held constant, and as the grid voltage is varied, readings are taken of grid voltage and plate current. When the grid voltage is zero, there will be a certain value of of plate current. If the plate current is to be reduced to zero by the grid voltage, a negative value of grid voltage is required. The set-up for taking the characteristic data is shown in Fig.5. In Fig. 6 is shown the characteristic curve thus obtained. It is the most useful of all the bulb characteristics, and use is made of it in studying the action of the bulb as a detecter in wireless

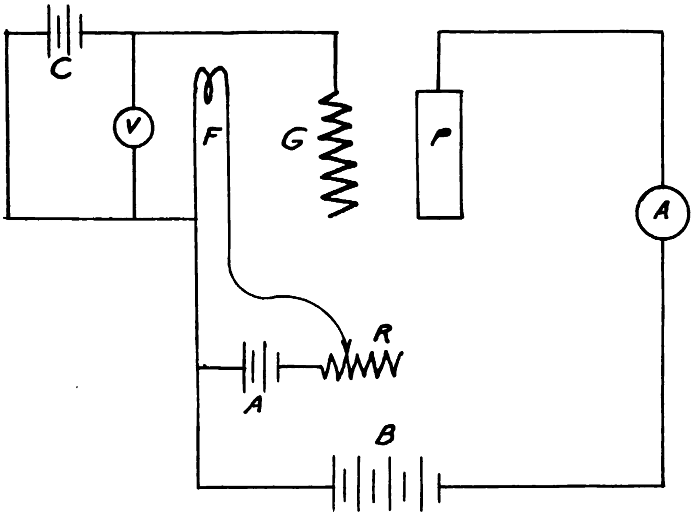
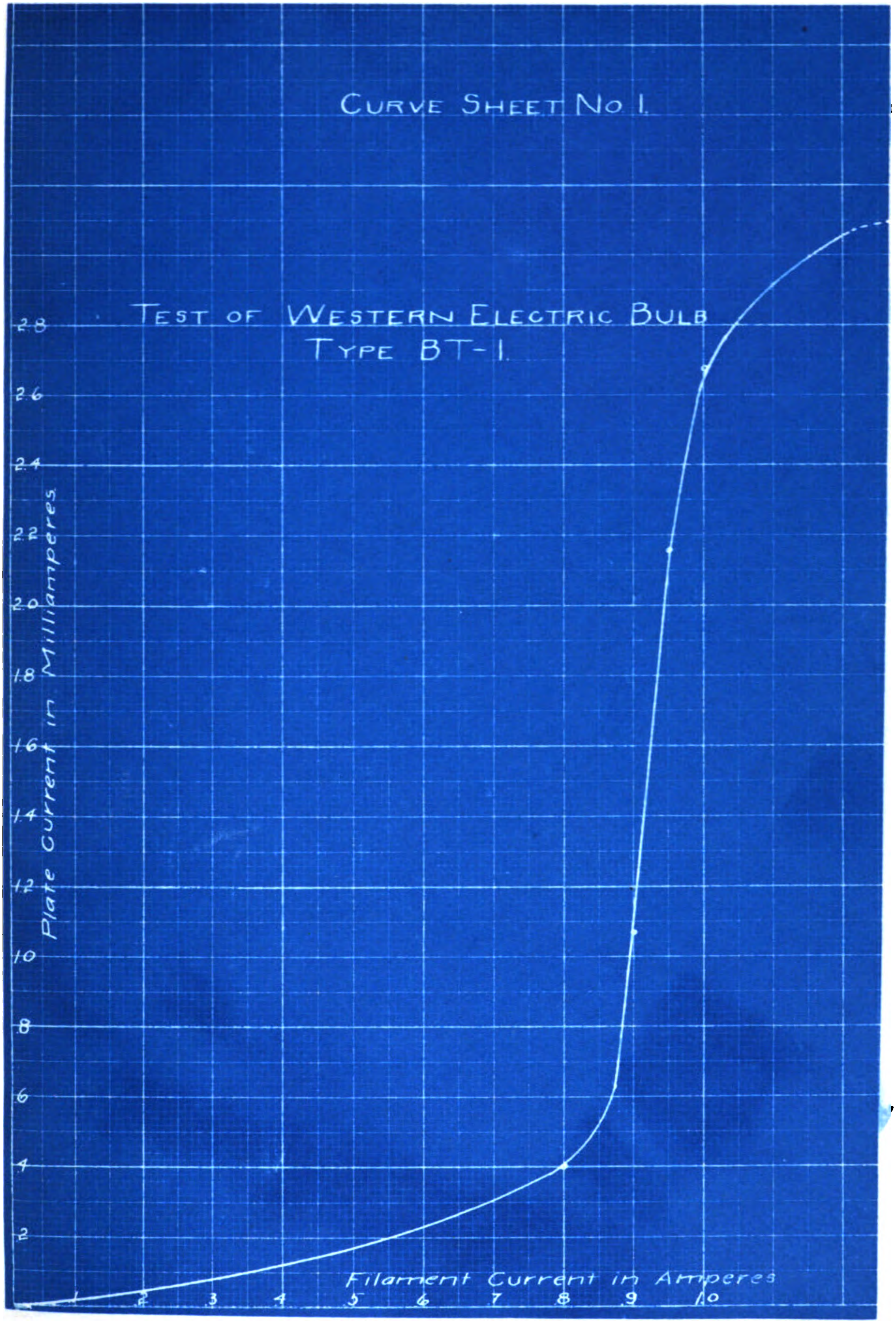
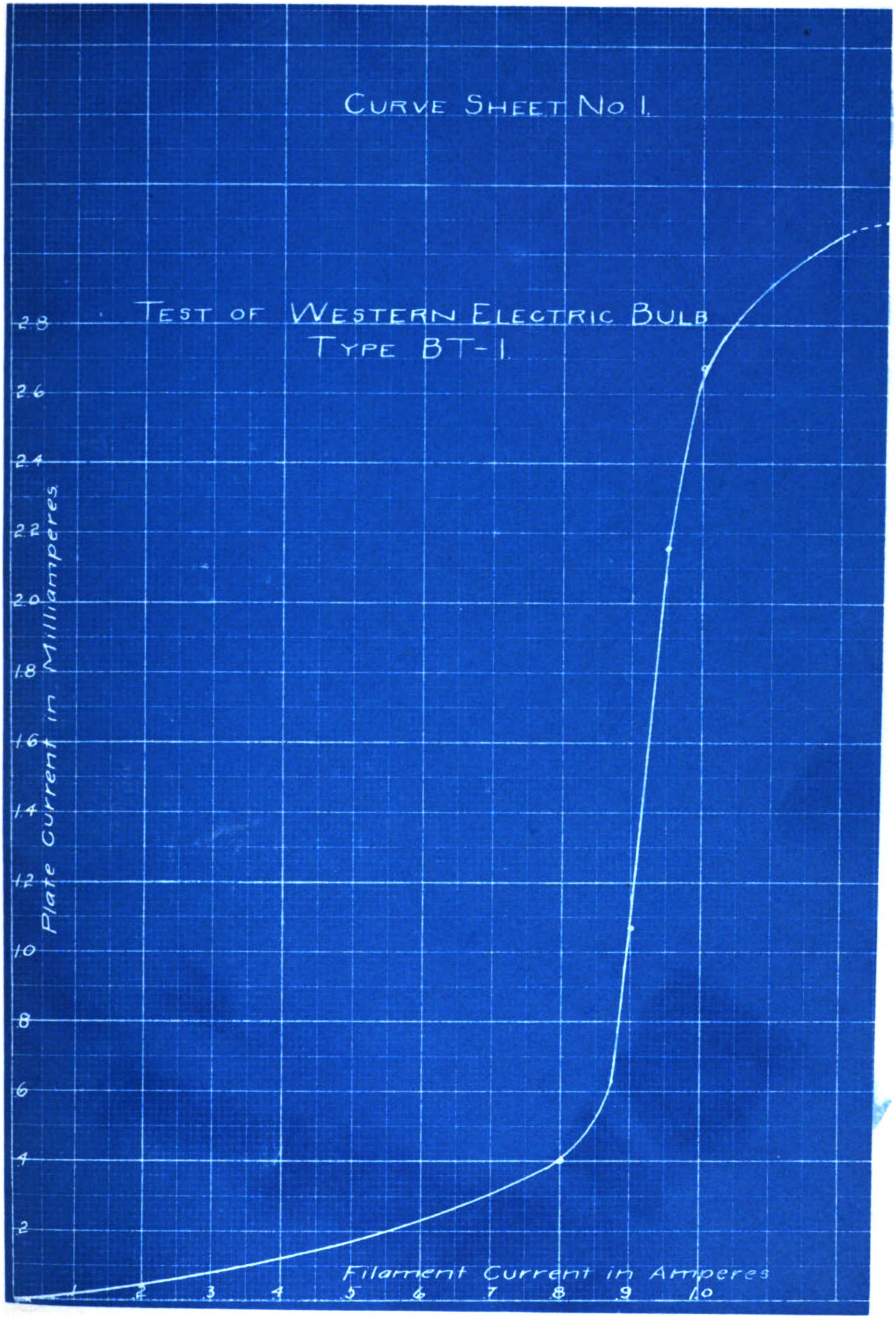


Fig. 5.



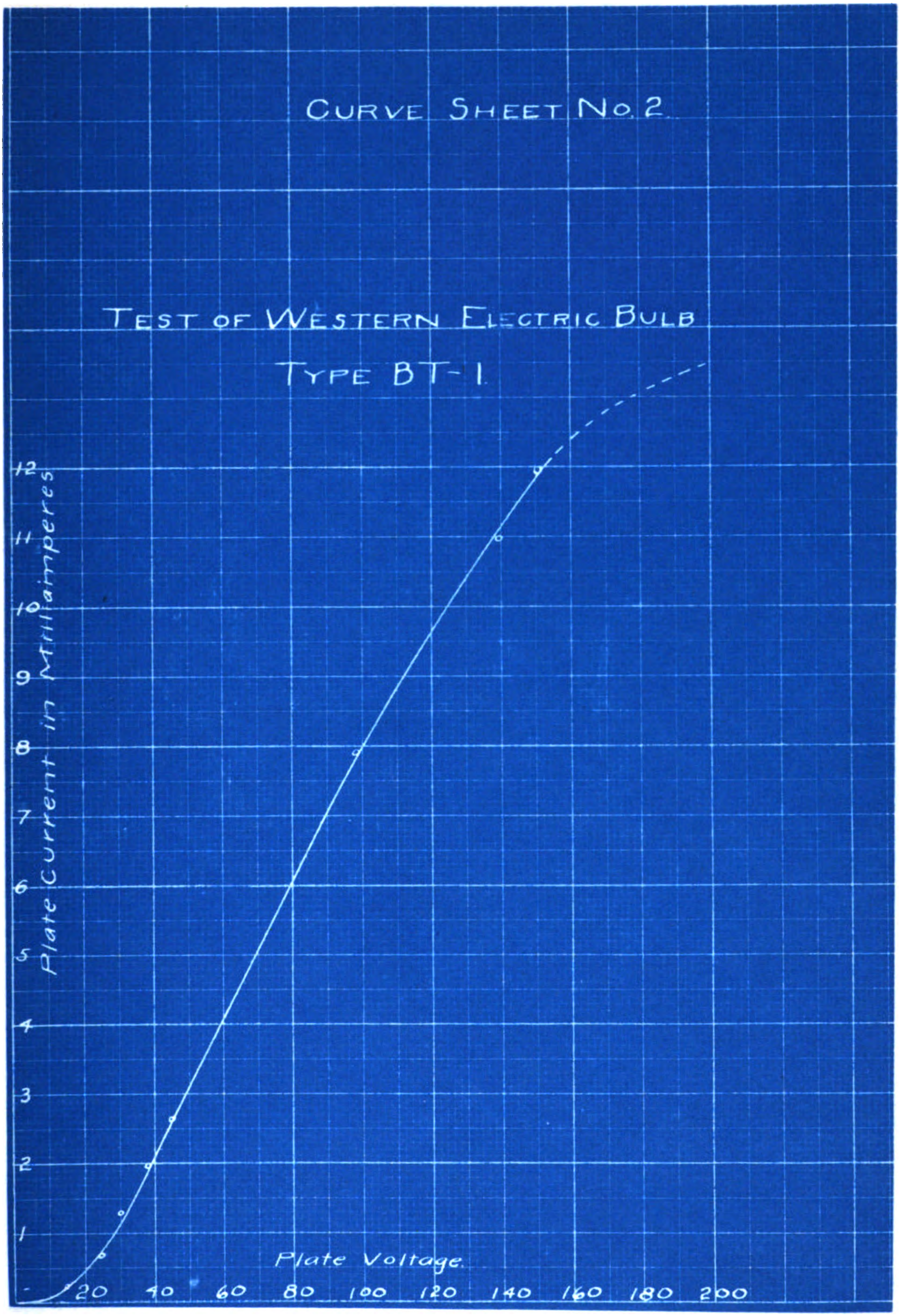
CURVE SHEET No 1.

TEST OF WESTERN ELECTRIC BULB
TYPE BT-1.



CURVE SHEET NO 1.

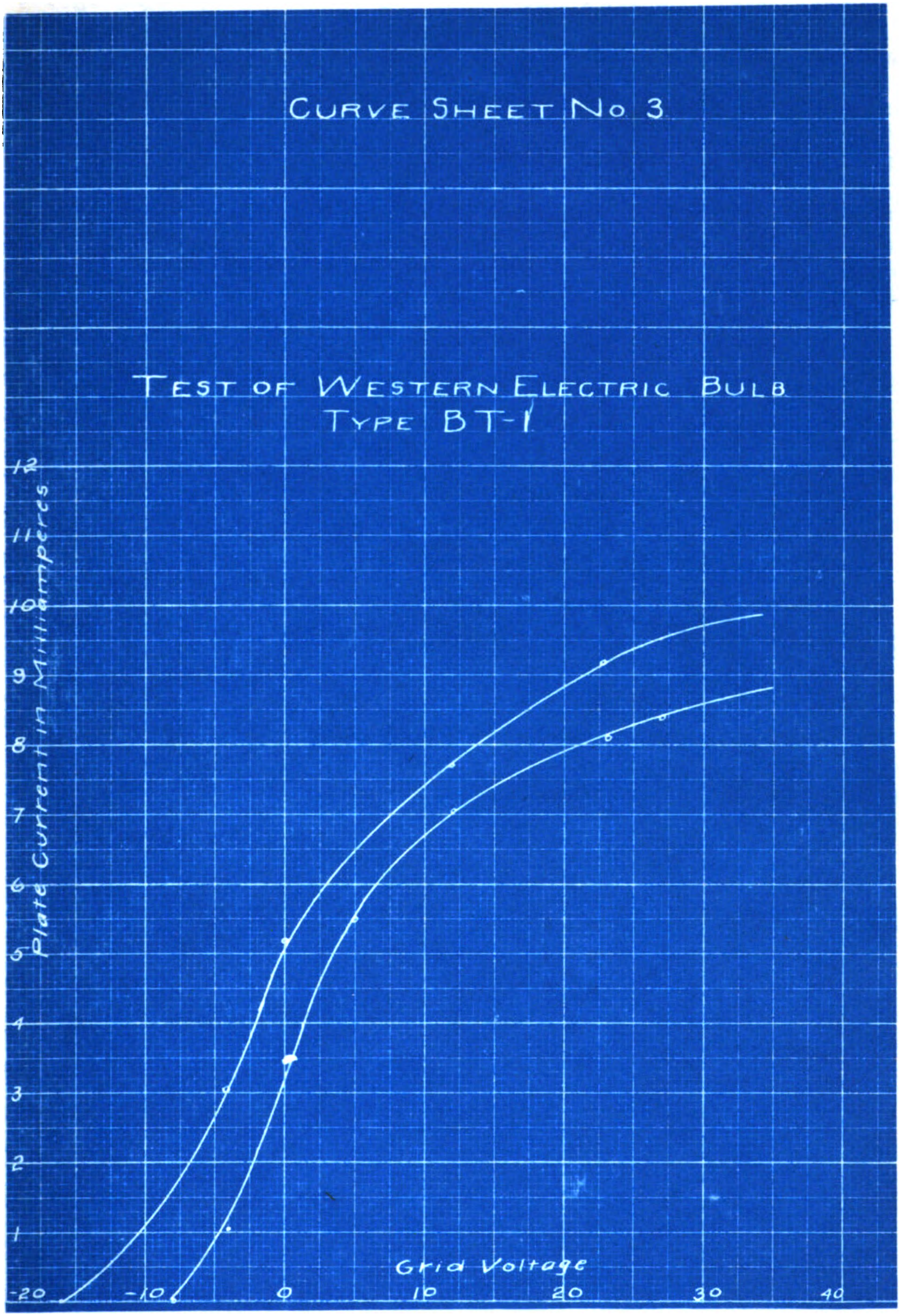
TEST OF WESTERN ELECTRIC BULB TYPE BT-1.



CURVE SHEET No. 2

TEST OF WESTERN ELECTRIC BULB

TYPE BT-1



CURVE SHEET No 3

TEST OF WESTERN ELECTRIC BULB
TYPE BT-1

telegraphy.

In Curve Sheets 1,2,and 3 are shown some actual characteristics plotted from data taken by the writer from a test of a three-element vacuum bulb made by the Western Electric Company for the Signal Corps of the United States Army. These features bring out the action of the vacuum bulb very well. In Sheet No.2 the plate voltage was not increased to a point where the bend in the curve would occur if the plate voltage were carried higher. The dotted portion of the curve shows the probable shape of the characteristic beyond the range of the experimental data.

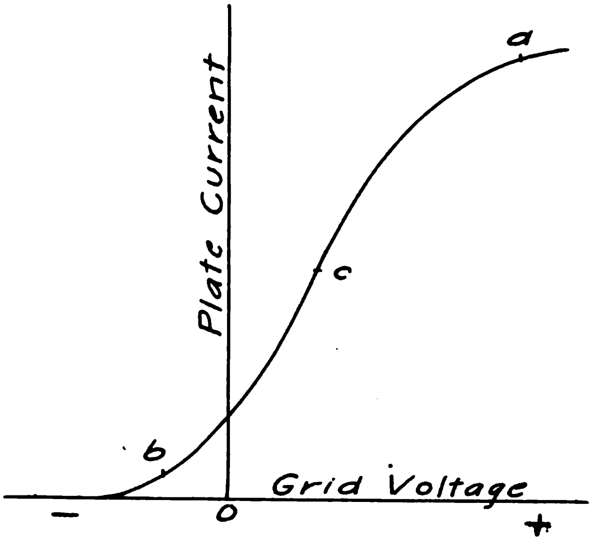


Fig. 6.

The action of the vacuum bulb in a radio telegraph receiving circuit will now be shown. Fig.7 shows the diagram of the simple Armstrong circuit using a vacuum bulb as a detecter. There are a large number of circuits in use, but the function of the bulb is the same in all.

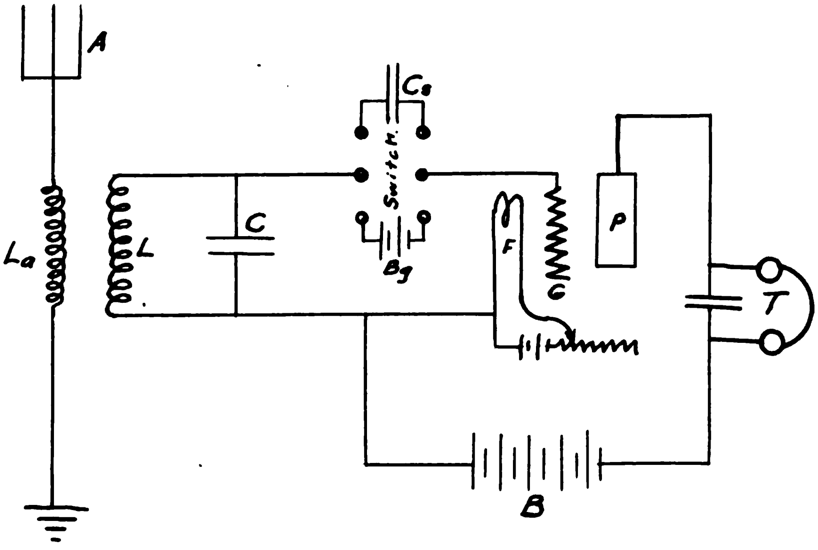


Fig. 7.

The incoming wave trains set up oscillations in the aerial circuit, which induces oscillations in the tuned oscillation circuit CL. The variation in voltage across the condenser C due to the incoming oscillations is impressed upon the grid. Now, the grid may either contain a stopping condenser C_g or a battery B_g.

If it contains a battery B_g, the grid is maintained at a certain potential with respect to the negative filament, when there are no oscillations in the circuit CL. This voltage may be either negative or positive, and is adjusted so that the grid voltage is maintained at the upper bend in the curve as shown at "a" or the lower bend shown at "b", Fig.6. When working at either of these points on the curve, the rectfying effect of the bulb is made use of. When working on the upper bend of the curve, shown at "a", the grid battery maintains the grid at a constant positive potential when there are no incoming oscillations. But when oscillations occur, the variable voltage due to the oscillations is impressed on the grid, causing the grid voltage to oscillate about its normal value. The voltage impressed upon the grid by the incoming oscillations is an alternating one, and has equal variations in the positive and negative directions. But the curve

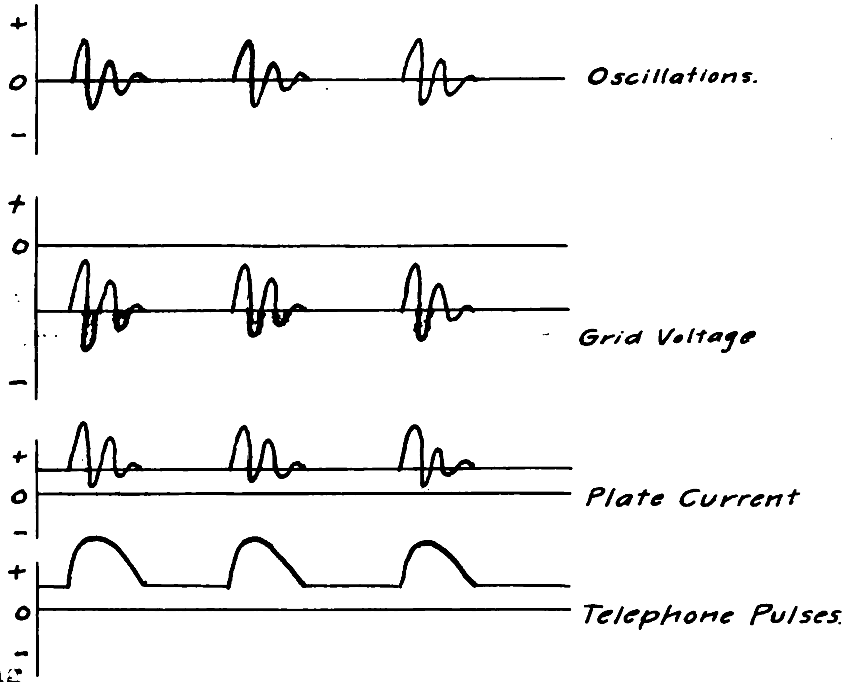


Fig. 8.

shows that when the grid voltage is varied by equal amounts in both positive and negative directions, the plate current does not vary in the same proportion as the grid voltage, but the pulses of current in the negative direction exceeds the pulses in the positive direction. This results in a pulsating plate current of spark frequency. The oscillations will also be repeated into the plate circuit, but they are above the audible frequency and will not be heard in the telephones. The action of the bulb under these conditions is shown in Fig.9. When operating at the point "b" on the lower part of the curve, the action is the same except that the plate current pulses are in the opposite direction. In Fig.8 is shown the current and voltage curves for the bulb when operating at the lower bend of the curve.

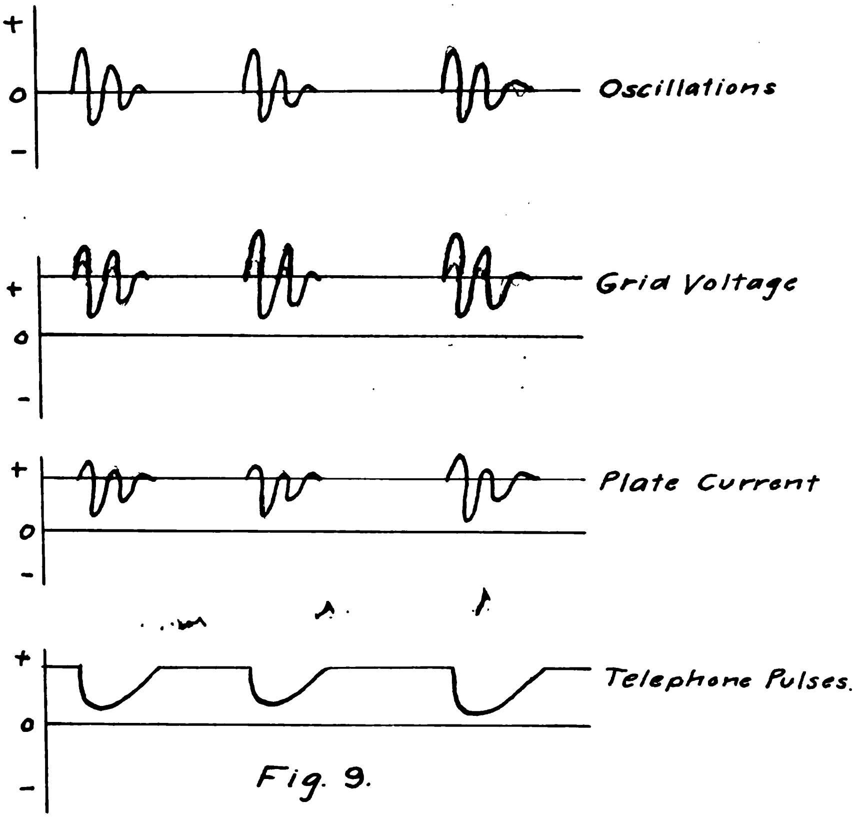


Fig. 9.

Now suppose that a stopping condenser is used instead of the grid battery. Here the action is different, and the bulb should be operated on the straight part of the characteristic curve as shown at point "c", Fig.6. When there are no incoming oscillations, there will be a continuous flow of current from the plate to filament, or the electrons flow from filament to plate. The grid is interposed

between the plate and filament, and is connected to the stopping condenser. Then when there are no oscillations in the circuit CL, the grid will be maintained at a definite potential, either positive or negative depending upon the shape of the characteristic curve for any particular bulb. When an incoming wave train sets the aerial circuit and the circuit CL into oscillation, the grid potential oscillates about its normal value. When the grid becomes positive with respect to its normal value, there will be an increase in the electrons flowing to it, and while on the negative half of the wave, there will be a slight reduction in the number of electrons flowing to it, but this reduction will be less than the increase due to the positive half of the wave. The result is that there is a decrease in plate current for every wave train, and this decrease is a single pulse for each wave train. The high frequency oscillations will be repeated into the plate circuit, but they are above audio frequency and will not be heard in the telephones. In Fig.10 is shown the action of the bulb when used with a stopping condenser.

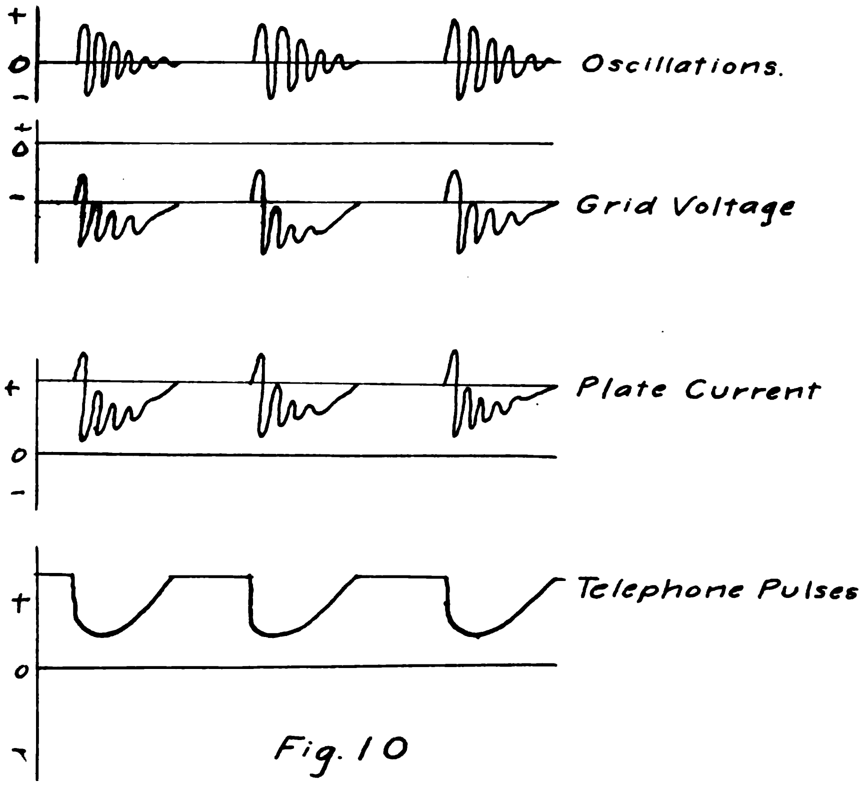


Fig. 10

CHAPTER II.

THE OPEN-AIR THERMIONIC DETECTER.

The open-air thermionic detecter consists of three elements, the filament, plate and grid. The function of these elements is exactly the same as that of the three elements of the audion bulb. Therefore, radio circuits using the open air detecter are similar to radio circuits using the audion as far as the circuit itself is concerned, but there is a great difference in the currents, voltages, etc., used in the operation of these circuits.

The filament used in the open-air detecter is a Nernst glower. The glower has a negative temperature coefficient, and is not a conductor of electricity when cold, but becomes a conductor when heated. On account of its negative temperature coefficient, a ballast resistance must be used in series with it. In starting the glower, it must be heated before it begins to conduct, and the current must be maintained constant at about 1.2 amperes.

The plate element consists of two plates connected together, thus giving a plate element of double the area of a single plate. The plates are made of brass, lined with a thin sheet of platinum which is necessary to withstand the intense heat of the glower. The dimensions of the plate are shown in Plate I. Each plate is 5/8" x 3/4" x 1/16", and has an area of 15/32 sq.in., or a combined plate area of 15/16 sq.in.

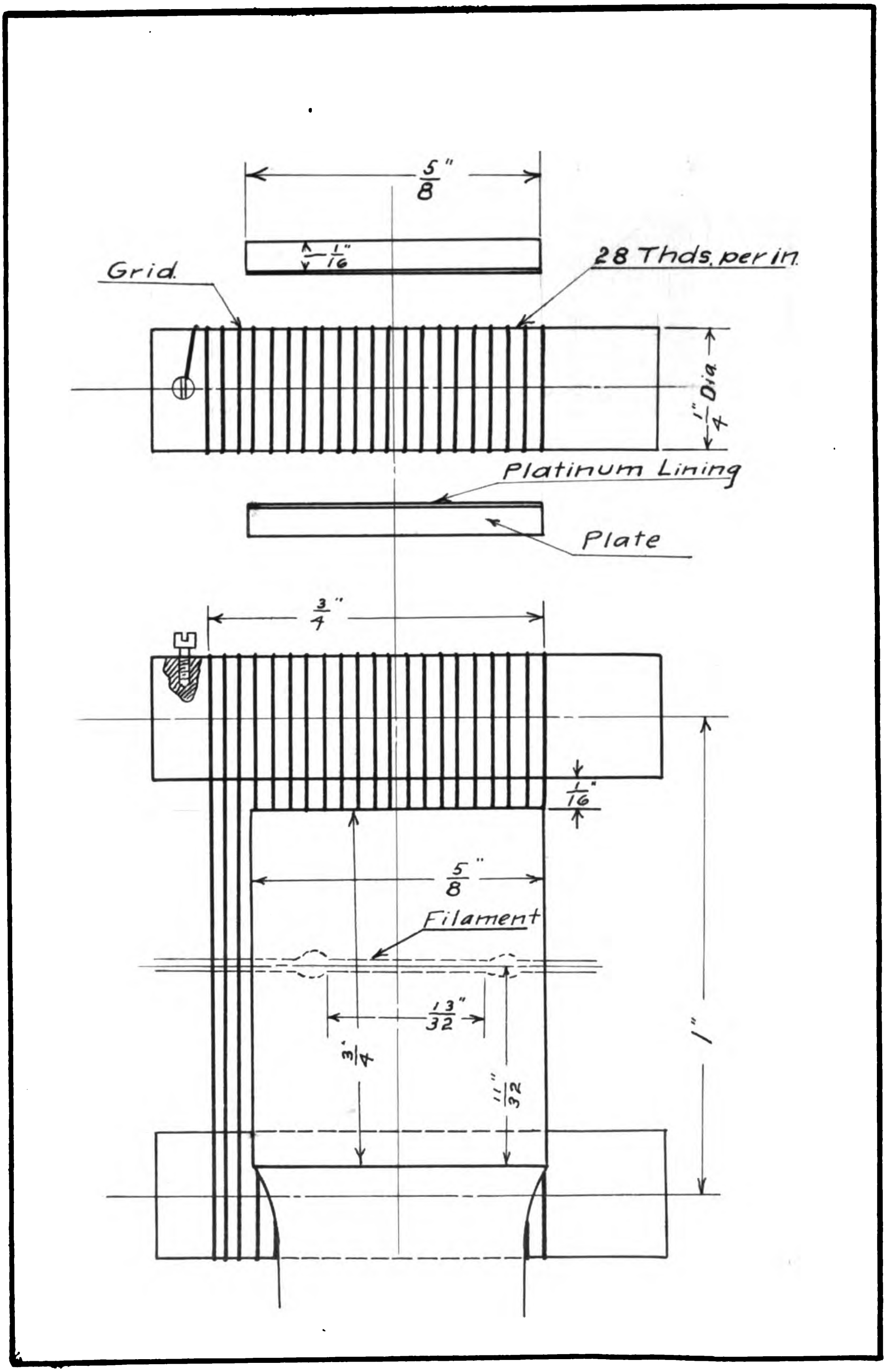

5/8"
1/16"
Grid
28 Thds. per in.
1/4" Dia.
Platinum Lining
Plate
3/4"
1/16"
5/8"
Filament
13/32"
3/4"
11/32"
1"

PLATE I.

The grid consists of platinum wire, having a diameter of .005 inch. This wire is wound on two arbors made of German Silver, each arbor having a diameter of $\frac{1}{4}$ inch, and a winding space $\frac{3}{4}$ inch wide. In Plate I are shown two views of the three elements, and in Fig.11, two views of the grid are shown. The length of wire composing the grid can be varied by varying the number of threads per inch on the arbors, or by winding the wire in only part of the grooves on the arbor surface. The grooves on the surface of the arbor are for the purpose of holding the grid wires in place, and are made a depth equal to the diameter of the wire, so that the surface of the grid wire will be flush with the surface of the arbor.

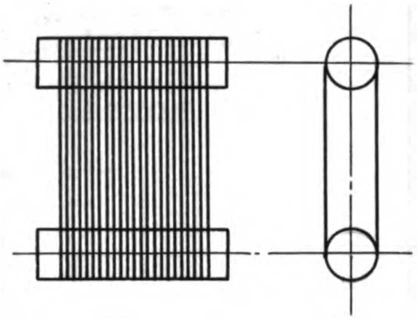


Fig. 11.

In Plate II is shown a sectional view of the assembled detecter, and in Plate I, a top and side view are shown. The plate spacing, or the distance between plate and grid is adjustable, and may be adjusted by means of the adjusting screws shown in Plate I.

The electrical connections are made by means of terminals at the base. The grid terminal connects to the metal post supporting the arbors on which the grid wire is wound, and the plate terminal connects to the post supporting the plates. The glower is supported by two upright brass posts containing slots for the lead-in wires. All parts of the plate and plate support are mounted on a marble base to give good insulation, which is

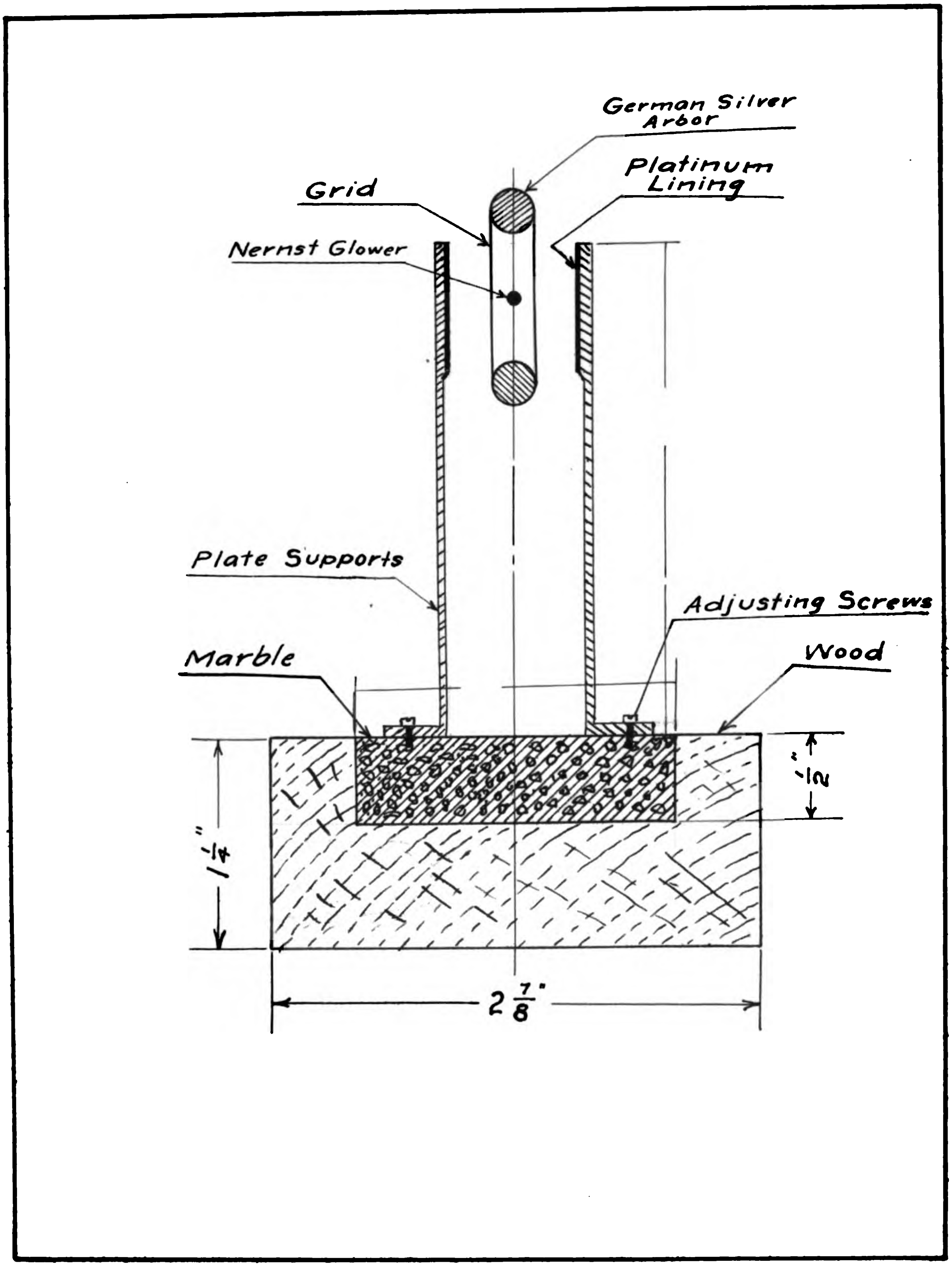

German Silver Arbor
Platinum Lining
Grid
Nernst Glower
Plate Supports
Adjusting Screws
Marble
Wood
1/2"
1 1/4"
2 7/8"

PLATE II.

necessary on account of the high plate voltage.

In all of the experimental work, the glower current is maintained at 1.2 amperes, as this is the highest current that can be used without causing **disintegration** of the glower. The plate is designed to withstand any voltage up to 1200 volts.

In using the detecter in a radio circuit for receiving, a battery or a stopping condenser may be used in the grid circuit.

DATA SHEET NO.1.

Mounting No.3.   Plate spacing = 14 mm.

FILAMENT CURRENT. Amperes	GRID VOLTS.	GRID CURRENT. Microamperes.	PLATE VOLTS.	PLATE CURRENT Microamperes.
1.2	-100	-.76	500	0
1.2	-80	-.64	500	0
1.2	-60	-.58	500	0
1.2	-40	-.47	500	0
1.2	-20	-.40	500	4.2
1.2	0	-.33	500	18.0
1.2	20	-.22	500	45.0
1.2	40	-.02	500	85.0
1.2	50	.32	500	90.7
1.2	60	1.4	500	114.
1.2	70	3.6	500	141
1.2	80	8.4	500	168
1.2	90	25.0	500	204
1.2	100	27.0	500	251.

DATA SHEET NO.2.

Mounting No.3. Plate spacing = 14 mm.

FILAMENT CURRENT. Amperes.	GRID VOLTS.	GRID CURRENT. Microamperes.	PLATE VOLTS.	PLATE CURRENT. Microamperes.
1.2	-100	-.62	700	.3
1.2	-80	-.56	700	.5
1.2	-60	-.48	700	.8
1.2	-40	-.40	700	6.
1.2	-20	-.34	700	23.
1.2	0	-.27	700	52 .
1.2	20	-.18	700	100.
1.2	30	-.16	700	129
1.2	40	-.14	700	157
1.2	50	-.13	700	197
1.2	60	0	700	228
1.2	70	.24	700	262
1.2	80	.62	700	309
1.2	90	2.0	700	332
1.2	100	3.0	700	374
1.2	110	7.0	700	405

DATA SHEET NO.2.

Mounting No.3. Plate spacing = 14 mm.

FILAMENT CURRENT. Amperes.	GRID VOLTS.	GRID CURRENT. Microamperes.	PLATE VOLTS.	PLATE CURRENT. Microamperes.
1.2	-100	-.62	700	.3
1.2	-80	-.56	700	.5
1.2	-60	-.48	700	.8
1.2	-40	-.40	700	6.
1.2	-20	-.34	700	23.
1.2	0	-.27	700	52 .
1.2	20	-.18	700	100.
1.2	30	-.16	700	129
1.2	40	-.14	700	157
1.2	50	-.15	700	197
1.2	60	0	700	228
1.2	70	.24	700	262
1.2	80	.62	700	309
1.2	90	2.0	700	332
1.2	100	3.0	700	374
1.2	110	7.0	700	405

DATA SHEET NO.3.

Mounting No.3.   Plate spacing = 14 mm.

FILAMENT CURRENT. Amperes.	GRID VOLTS.	GRID CURRENT. Microamperes.	PLATE VOLTS.	PLATE CURRENT. Microamperes.
1.2	-100	-.56	900	1.6
1.2	-80	-.46	900	2.3
1.2	-60	-.40	900	7.8
1.2	-40	-.32	900	28.
1.2	-20	-.43	900	63.
1.2	0	-20	900	109.
1.2	20	-.16	900	181
1.2	40	-.10	900	254
1.2	60	-.02	900	324
1.2	80	0	900	400
1.2	90	.04	900	431
1.2	100	.26	900	462
1.2	110	.80	900	505

DATA SHEET NO.4.

Mounting No.3.   Plate Spacing = 14 mm.

FILAMENT CURRENT. Amperes.	GRID VOLTS.	GRID CURRENT. Micramperes.	PLATE VOLTS.	PLATE CURRENT. Microamperes.
1.2	-100	-.82	300	0
1.2	-80	-.75	300	0
1.2	-60	-.60	300	.2
1.2	-40	-.54	300	.2
1.2	-20	-.45	300	.2
1.2	0	-.40	300	2.3
1.2	20	-.28	300	13.
1.2	30	-.04	300	21.
1.2	40	2.0	300	31.
1.2	50	4.4	300	42.
1.2	60	14.0	300	53.
1.2	70	27.0	300	63.

DATA SHEET NO.5.

Mounting No.3. Plate spacing = 14 mm.

FILAMENT CURRENT. Amperes.	GRID VOLTS.	GRID CURRENT. Microamperes.	PLATE VOLTS.	PLATE CURRENT. Microamperes.
1.2	-80	-.98	100	0
1.2	-60	-.84	100	0
1.2	-40	-.70	100	0
1.2	-20	-.60	100	0
1.2	0	-.44	100	0
1.2	10	-.38	100	0
1.2	15	-.04	100	0
1.2	20	1.60	100	.4
1.2	25	5.00	100	1.1
1.2	30		100	1.6

DATA SHEET NO.6.

Mounting No.3. Plate spacing = 14 mm.

FILAMENT CURRENT. Amperes.	GRID VOLTS.	GRID CURRENT. Microamperes.	PLATE VOLTS.	PLATE CURRENT. Microamperes.
1.2	-80	-.80	300	0
1.2	-60	-.64	300	0
1.2	-40	-.58	300	0
1.2	-20	-.44	300	0
1.2	0	-.35	300	0
1.2	20	-.16	300	6.3
1.2	25	.16	300	10.5
1.2	30	1.2	300	15.2
1.2	40	6.0	300	28.0
1.2	50		300	53.5
1.2	60		300	70.0
1.2	80		300	93.0

DATA SHEET NO.7.

FILAMENT CURRENT. Amperes.	GRID VOLTS.	GRID CURRENT. Microamperes.	PLATE VOLTS.	PLATE CURRENT Microamperes.
1.2	-80	-.74	500	0
1.2	-60	-.60	500	0
1.2	-40	-.44	500	.2
1.2	-20	-.38	500	.4
1.2	0	-.30	500	1.8
1.2	20	-.18	500	15.0
1.2	30	-.12	500	30.0
1.2	35	.04	500	40.0
1.2	40	.50	500	52.0
1.2	50	1.80	500	74.0
1.2	60	5.40	500	105.0
1.2	70	16.00	500	140.0
1.2	80		500	179.0
1.2	100		500	253.0
1.2	110		500	282.0

DATA SHEET NO.8.

Mounting No.3. Plate spacing = 14 mm.

FILAMENT CURRENT, Amperes.	GRID VOLTS.	GRID CURRENT. Microamperes.	PLATE VOLTS.	PLATE CURRENT. Microamperes.
1.2	-80	-.60	700	0
1.2	-60	-.50	700	0
1.2	-40	-.40	700	0
1.2	-20	-.32	700	0
1.2	0	-.24	700	5.2
1.2	20	-.16	700	26.2
1.2	40	-.02	700	74.0
1.2	60	1.00	700	145.0
1.2	80	6.00	700	227.0
1.2	100		700	305.0
1.2	110		700	362.0

DATA SHEET NO.9.

Mounting No.3. Plate spacing = 14 mm.

FILAMENT CURRENT. Amperes.	GRID VOLTS.	GRID CURRENT. Microamperes.	PLATE VOLTS.	PLATE CURRENT. Microamperes.
1.2	-80	-.60	900	2.38
1.2	-60	-.46	900	3.82
1.2	-40	-.34	900	6.20
1.2	-20	-.30	900	9.50
1.2	0	-.20	900	15.70
1.2	20	-.12	900	49.00
1.2	40	0	900	105.00
1.2	60	.04	900	172.00
1.2	80	.84	900	253.00
1.2	100	3.60	900	346.00
1.2	110	8.00	900	400.00

DATA SHEET NO.10.

Mounting No.2. Gauze Grid.

FILAMENT CURRENT. Amperes.	GRID VOLTS.	GRID CURRENT. Microamperes.	PLATE VOLTS.	PLATE CURRENT. Microamperes.
1.2	-80	-2.04	300	0
1.2	-60	-1.60	300	0
1.2	-40	-1.26	300	0
1.2	-20	- .98	300	0
1.2	0	- .78	300	0
1.2	20	- .40	300	0
1.2	25	.04	300	.60
1.2	30	.86	300	1.20
1.2	35	2.30	300	2.50
1.2	40	3.60	300	3.70
1.2	45	9.20	300	6.50
1.2	60		300	22.00
1.2	80		300	40.00

DATA SHEET NO.11.

Mounting No.2.   Gauze Grid.

FILAMENT CURRENT. Amperes.	GRID VOLTS.	GRID CURRENT. Microamperes.	PLATE VOLTS.	PLATE CURRENT. Microamperes.
1.2	-80	-2.00	500	0
1.2	-60	-1.60	500	0
1.2	-40	-1.32	500	0
1.2	-20	-1.06	500	0
1.2	0	- .84	500	0
1.2	20	- .46	500	.7
1.2	25	- .20	500	1.3
1.2	30	.44	500	2.6
1.2	35	1.20	500	3.8
1.2	40	2.60	500	5.7
1.2	50	12.00	500	18.0
1.2	60		500	35.0
1.2	80		500	68.0
1.2	100		500	100.00

DATA SHEET NO.12.

Mounting No.2. Gauze Grid.

FILAMENT CURRENT. Amperes.	GRID VOLTS.	GRID CURRENT. Microamperes.	PLATE VOLTS.	PLATE CURRENT. Microamperes.
1.2	-80	-1.86	700	0
1.2	-60	-1.46	700	0
1.2	-40	-1.20	700	0
1.2	-20	- .96	700	0
1.2	0	- .76	700	0
1.2	20	- .44	700	1.2
1.2	25	- .26	700	2.2
1.2	30	.20	700	3.3
1.2	35	.90	700	5.0
1.2	40	2..0	700	7.0
1.2	50	5.0	700	13.0
1.2	60	19.0	700	32.0
1.2	80		700	75.0
1.2	100		700	115.0
1.2	110		700	130.0

DATA SHEET NO.13.

Mounting No.2. Gauze Grid.

FILAMENT CURRENT Amperes.	GRID VOLTS.	GRID CURRENT. Microamperes.	PLATE VOLTS.	PLATE CURRENT. Microamperes.
1.2	-80	-1.9	900	0
1.2	-60	-1.5	900	0
1.2	-40	-1.24	900	0
1.2	-20	-1.0	900	0
1.2	0	- .80	900	1.0
1.2	20	- .54	900	2.4
1.2	30	0	900	5.3
1.2	40	1.4	900	8.5
1.2	50	3.8	900	13.5
1.2	60	10.0	900	26.5
1.2	70	24.0	900	53.0
1.2	90		900	97.0
1.2	110		900	127.5

DATA SHEET NO.14.

Mounting No.2. Grid 6 mm. Coarse.

FILAMENT CURRENT. Amperes.	GRID VOLTS.	GRID CURRENT. Microamperes.	PLATE VOLTS.	PLATE CURRENT. Microamperes.
1.2	-80	-1.40	300	0
1.2	-60	-1.12	300	0
1.2	-40	- .92	300	0
1.2	-20	- .70	300	0
1.2	0	- .52	300	0
1.2	20	- .16	300	.4
1.2	25	.20	300	1.2
1.2	30	.90	300	2.2
1.2	35	1.84	300	3.6
1.2	40	3.40	300	5.3
1.2	50	22.00	300	23.5
1.2	60		300	36.0
1.2	70		300	47.0
1.2	80		300	64.0
1.2	90		300	77.0
1.2	100		300	83.0

DATA SHEET NO.14.

Mounting No.2. Grid 6 mm. Coarse.

FILAMENT CURRENT. Amperes.	GRID VOLTS.	GRID CURRENT. Microamperes.	PLATE VOLTS.	PLATE CURRENT. Microamperes.
1.2	-80	-1.40	300	0
1.2	-60	-1.12	300	0
1.2	-40	- .92	300	0
1.2	-20	- .70	300	0
1.2	0	- .52	300	0
1.2	20	- .16	300	.4
1.2	25	.20	300	1.2
1.2	30	.90	300	2.2
1.2	35	1.84	300	3.6
1.2	40	3.40	300	5.3
1.2	50	22.00	300	23.5
1.2	60		300	36.0
1.2	70		300	47.0
1.2	80		300	64.0
1.2	90		300	77.0
1.2	100		300	83.0

DATA SHEET. NO.15.

Mounting No.2. Grid 6 mm. Coarse.

FILAMENT CURRENT. Amperes.	GRID VOLTS.	GRID CURRENT. Microamperes,	PLATE VOLTS.	PLATE CURRENT. Microamperes.
1.2	-80	-1.56	500	0
1.2	-60	-1.20	500	0
1.2	-40	-1.00	500	0
1.2	-20	- .78	500	0
1.2	0	- .58	500	0
1.2	20	- .36	500	.9
1.2	25	- .10	500	2.2
1.2	30	.40	500	3.8
1.2	35	.96	500	5.4
1.2	40	2.20	500	7.5
1.2	50	7.00	500	20.0
1.2	60		500	38.0
1.2	80		500	73.0
1.2	100		500	115.0
1.2	110		500	113.0

DATA SHEET NO.16.

Mounting No.2. Grid 6 mm. Coarse.

FILAMENT CURRENT. Amperes.	GRID VOLTS.	GRID CURRENT. Microamperes.	PLATE VOLTS.	PLATE CURRENT. Microamperes.
1.2	-80	-1.64	700	0
1.2	-60	-1.24	700	0
1.2	-40	-1.04	700	0
1.2	-20	- .82	700	0
1.2	0	- .64	700	0
1.2	20	- .42	700	2.1
1.2	30	.08	700	5.0
1.2	35	.64	700	7.5
1.2	40	1.56	700	9.8
1.2	50	4.60	700	17.5
1.2	60	11.00	700	33.0
1.2	80		700	48.7
1.2	100		700	78.0
1.2	110		700	130.0

DATA SHEET NO.17.

Mounting No.2. Grid 6 mm. Coarse.

FILAMENT CURRENT. Amperes.	GRID VOLTS.	GRID CURRENT. Microamperes.	PLATE VOLTS.	PLATE CURRENT. Microamperes.
1.2	-80	-1.64	900	0
1.2	-60	-1.34	900	0
1.2	-40	-1.06	900	2.0
1.2	-20	- .48	900	2.3
1.2	0	- .72	900	4.3
1.2	20	- .56	900	7.6
1.2	30	- .18	900	10.0
1.2	35	.20	900	13.5
1.2	40	.90	900	21.0
1.2	50	3.10	900	33.0
1.2	60	10.00	900	57.0
1.2	70		900	82.0
1.2	80		900	
1.2	100		900	137.0
1.2	110		900	149.0

DATA SHEET NO.18.

Mounting No.3. 12 mm. Plate Spacing.

FILAMENT CURRENT. Amperes.	GRID VOLTS.	GRID CURRENT. Microamperes.	PLATE VOLTS.	PLATE CURRENT. Microamperes.
1.2	-80	-1.20	400	0
1.2	-60	- .96	400	0
1.2	-40	- .74	400	0
1.2	-20	- .56	400	0
1.2	0	- .40	400	0
1.2	20	- .28	400	10.0
1.2	30	- .22	400	21.0
1.2	40	.04	400	40.0
1.2	45	.70	400	52.0
1.2	50	126.0	400	150.0
1.2	60		400	215.0
1.2	80		400	450.0
1.2	100		400	500.0
1.2	110		400	505.0

DATA SHEET NO.19.

Mounting No.3. 12 mm. Plate Spacing.

FILAMENT CURRENT. Amperes.	GRID VOLTS.	GRID CURRENT. Microamperes.	PLATE VOLTS.	PLATE CURRENT. Microamperes.
1.2	-80	-1.02	600	0
1.2	-60	- .76	600	0
1.2	-40	- .56	600	.5
1.2	-20	- .40	600	.5
1.2	0	- .30	600	1.8
1.2	20	- .22	600	16.0
1.2	40	- .12	600	58.0
1.2	60	.40	600	127.0
1.2	80	9.60	600	250.0
1.2	100	84.00	600	425.0
1.2	110	120.00	600	510.0

Grid and plate current jump off scale at 65 grid volts,and comes back again.

DATA SHEET NO.20.

Mounting No.3. 12 mm. plate spacing.

FILAMENT CURRENT. Amperes.	GRID VOLTS.	GRID CURRENT. Microamperes.	PLATE VOLTS.	PLATE CURRENT. Microamperes.
1.2	-80	-.94	800	1.0
1.2	-60	-.68	800	1.0
1.2	-40	-.50	800	1.0
1.2	-20	-.36	800	1.0
1.2	0	-.26	800	6.0
1.2	20	-.20	800	27.0
1.2	40	-.04	800	82.0
1.2	60	.08	800	170.0
1.2	80	.60	800	285.0
1.2	100	6.00	800	400.0
1.2	110	14.00	800	475.0

DATA SHEET NO.21.

Mounting No.3. 12 mm. Plate Spacing.

FILAMENT CURRENT. Amperes.	GRID VOLTS.	GRID CURRENT. Microamperes.	PLATE VOLTS.	PLATE CURRENT. Microamperes.
1.2	-80	-.92	1000	1.5
1.2	-60	-.64	1000	1.5
1.2	-40	-.46	1000	2.3
1.2	-20	-.36	1000	3.0
1.2	0	-.24	1000	12.5
1.2	20	-.16	1000	43.0
1.2	40	0	1000	105.0
1.2	60	.06	1000	215.0
1.2	80	.14	1000	325.0
1.2	100	.50	1000	430 .0
1.2	110	1.80		500.0

DATA SHEET NO.22.

Mounting No.3. 12 mm.Plate Spacing.

FILAMENT CURRENT. Amperes.	GRID VOLTS.	GRID CURRENT. Microamperes.	PLATE VOLTS.	PLATE CURRENT. Microamperes.
1.2	-80	-.88	300	0
1.2	-60	-.72	300	0
1.2	-40	-.46	300	0
1.2	-20	-.35	300	0
1.2	0	-.22	300	0
1.2	20	-.15	300	4.5
1.2	30	-.04	300	11.0
1.2	35	.14	300	13.0
1.2	50	.25	300	50.0
1.2	60		300	135.0
1.2	80		300	230.0
1.2	100		300	250.0
1.2	110		300	240.-

Grid and plate currents jump at 38 grid volts.

DATA SHEET NO.23.

Mounting No.3. 12 mm.Plate Spacing.

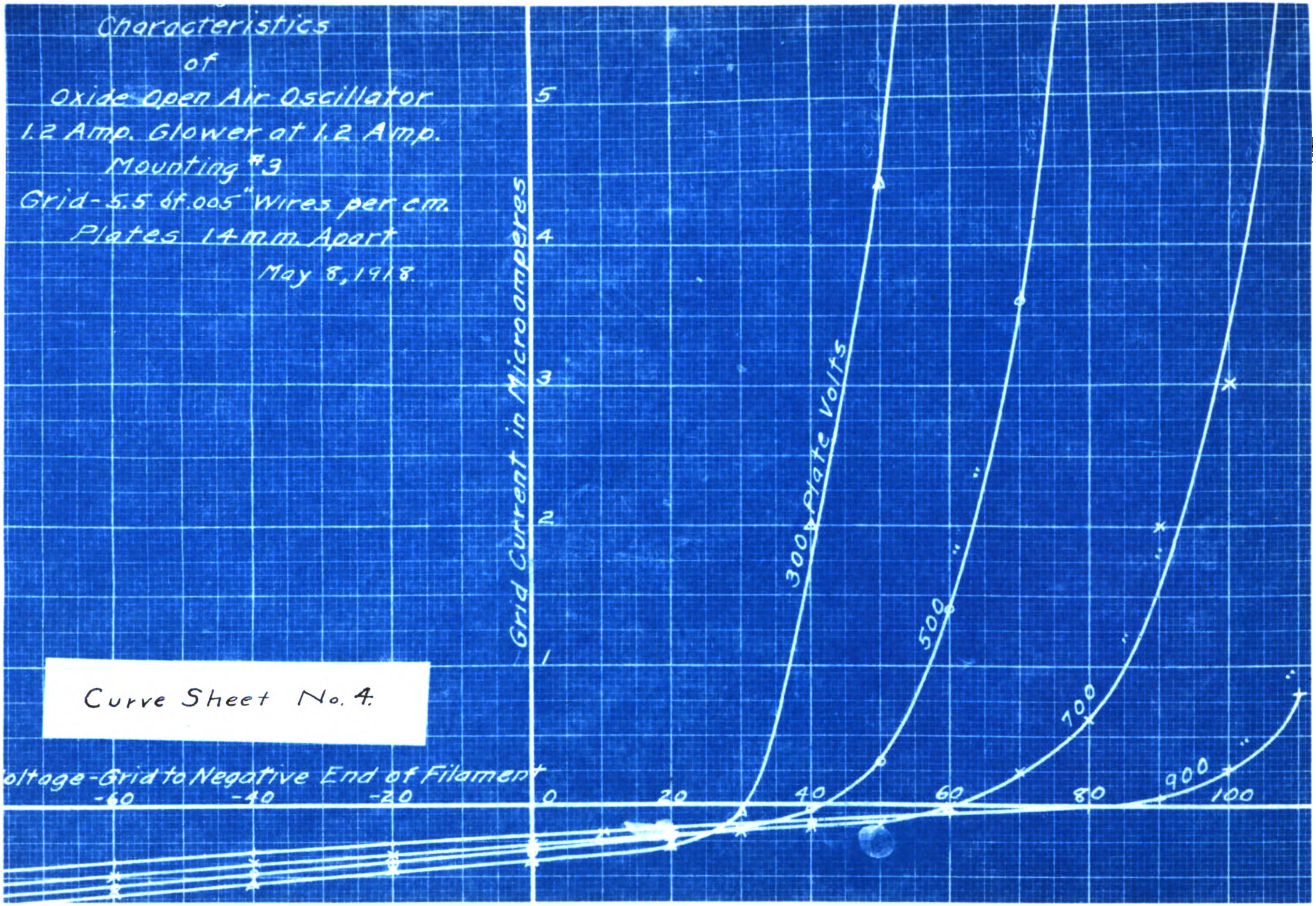
FILAMENT CURRENT. Amperes.	GRID VOLTS.	GRID CURRENT. Microamperes.	PLATE VOLTS.	PLATE CURRENT. Microamperes.
1.2	-80	-.98	200	0
1.2	-60	-.74	200	0
1.2	-40	-.52	200	0
1.2	-20	-.36	200	0
1.2	0	-.22	200	0
1.2	20	-.14	200	3.2
1.2	30	Jumps.	200	10.0
1.2	40		200	43.0
1.2	60		200	71.0
1.2	80		200	75.0
1.2	100		200	52.0
1.2	110		200	39.0

Grid and plate currents jump at 27 grid volts.

DATA SHEET NO.24.

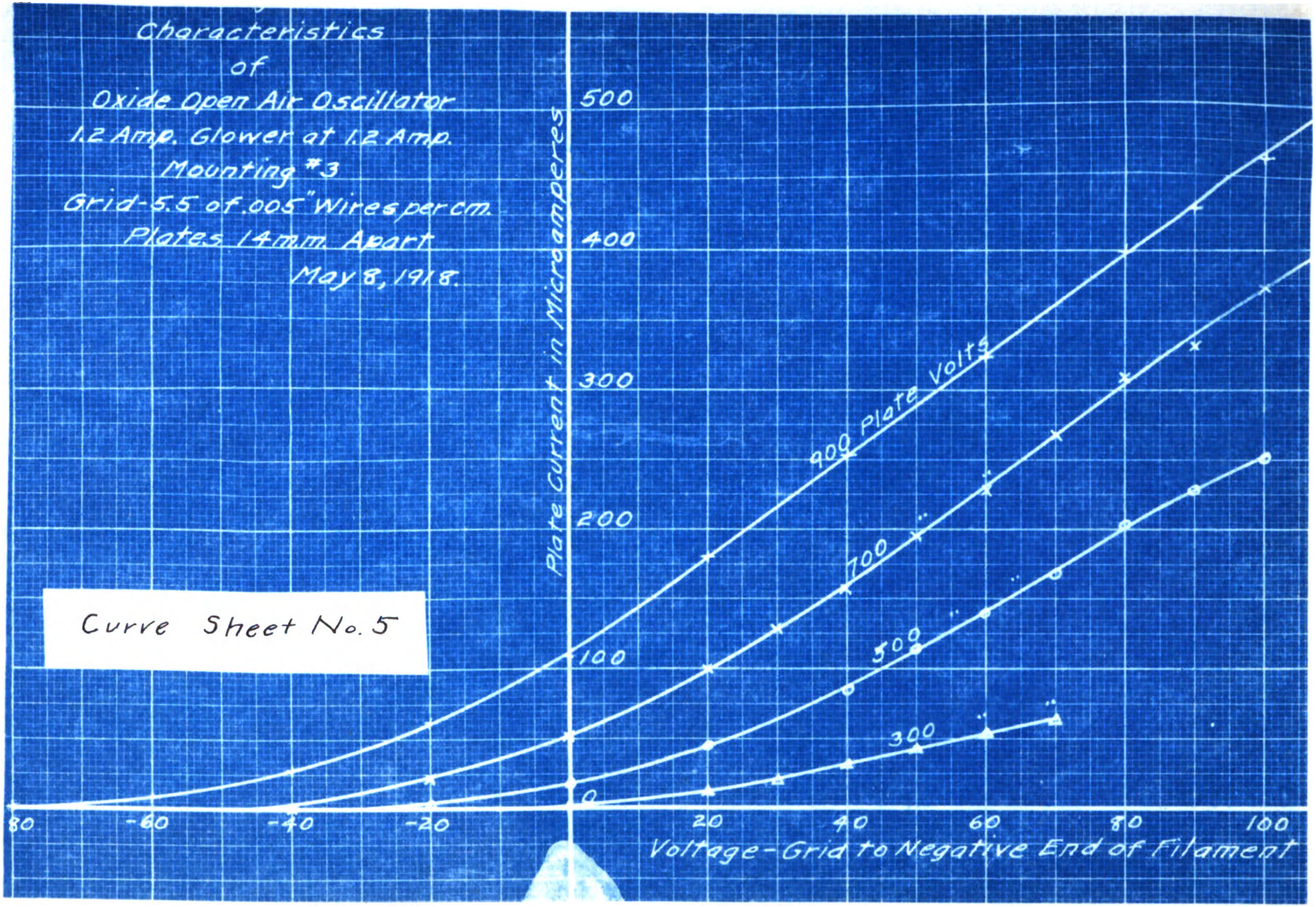
Mounting No.3. 12 mm. Plate Spacing.

FILAMET CURRENT. Amperes.	GRID VOLTS.	GRID CURRENT. Microamperes.	PLATE VOLTS.	PLATE CURRENT. Microamperes.
1.2	-80	-1.0	100	0
1.2	-60	- .80	100	0
1.2	-40	- .58	100	0
1.2	-20	- .40	100	0
1.2	0	- .24	100	0
1.2	20	2.0	100	2.0
1.2	30	48.0	100	9.2
1.2	40	120.0	100	11.5
1.2	60		100	8.5
1.2	80		100	3.0
1.2	100		100	.8
1.2	110		100	.4



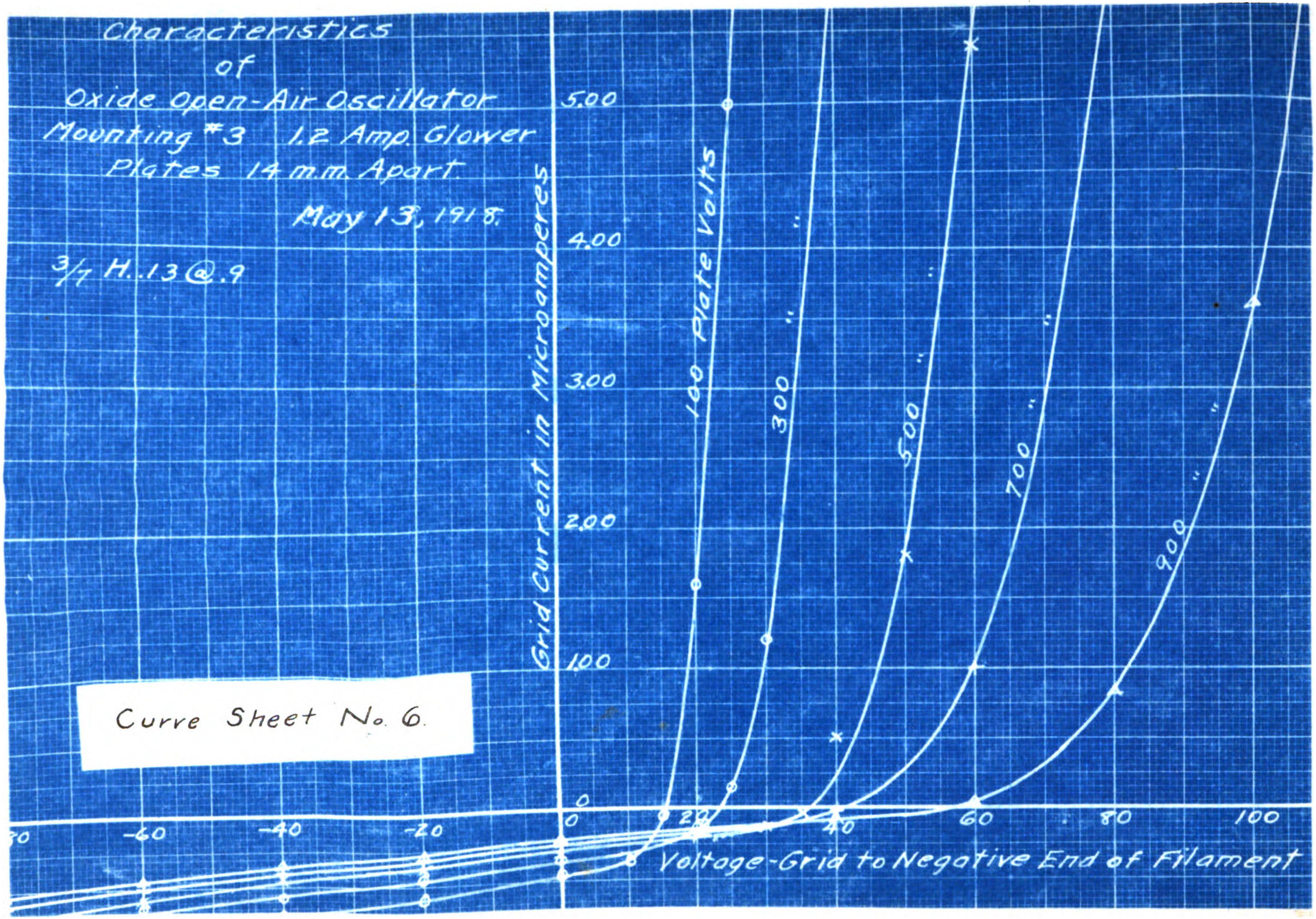
Characteristics
of
Oxide Open Air Oscillator
1.2 Amp. Glower at 1.2 Amp.
Mounting #3
Grid-5.5 of .005" Wires per cm.
Plates 14 m.m. Apart
May 8, 1918.

Curve Sheet No. 4.



Characteristics
of
Oxide Open Air Oscillator
1.2 Amp. Glower at 1.2 Amp.
Mounting #3
Grid-5.5 of .005" Wires per cm.
Plates 14 mm. Apart
May 8, 1918.

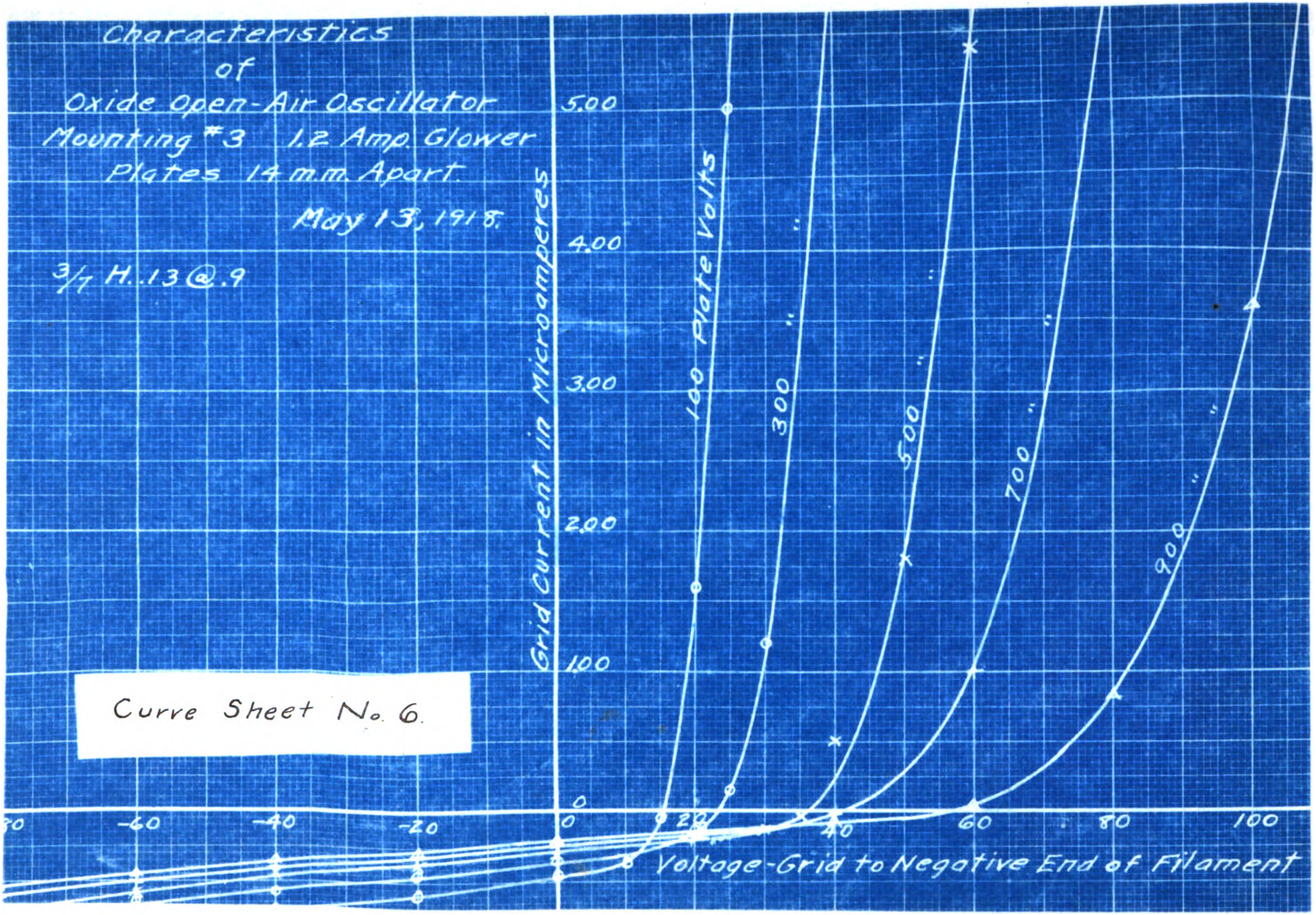
Curve Sheet No. 5



Characteristics
of
Oxide Open-Air Oscillator
Mounting #3 1.2 Amp. Glower
Plates 14 m.m. Apart.
May 13, 1918.

3/7 H. 13 @ .9

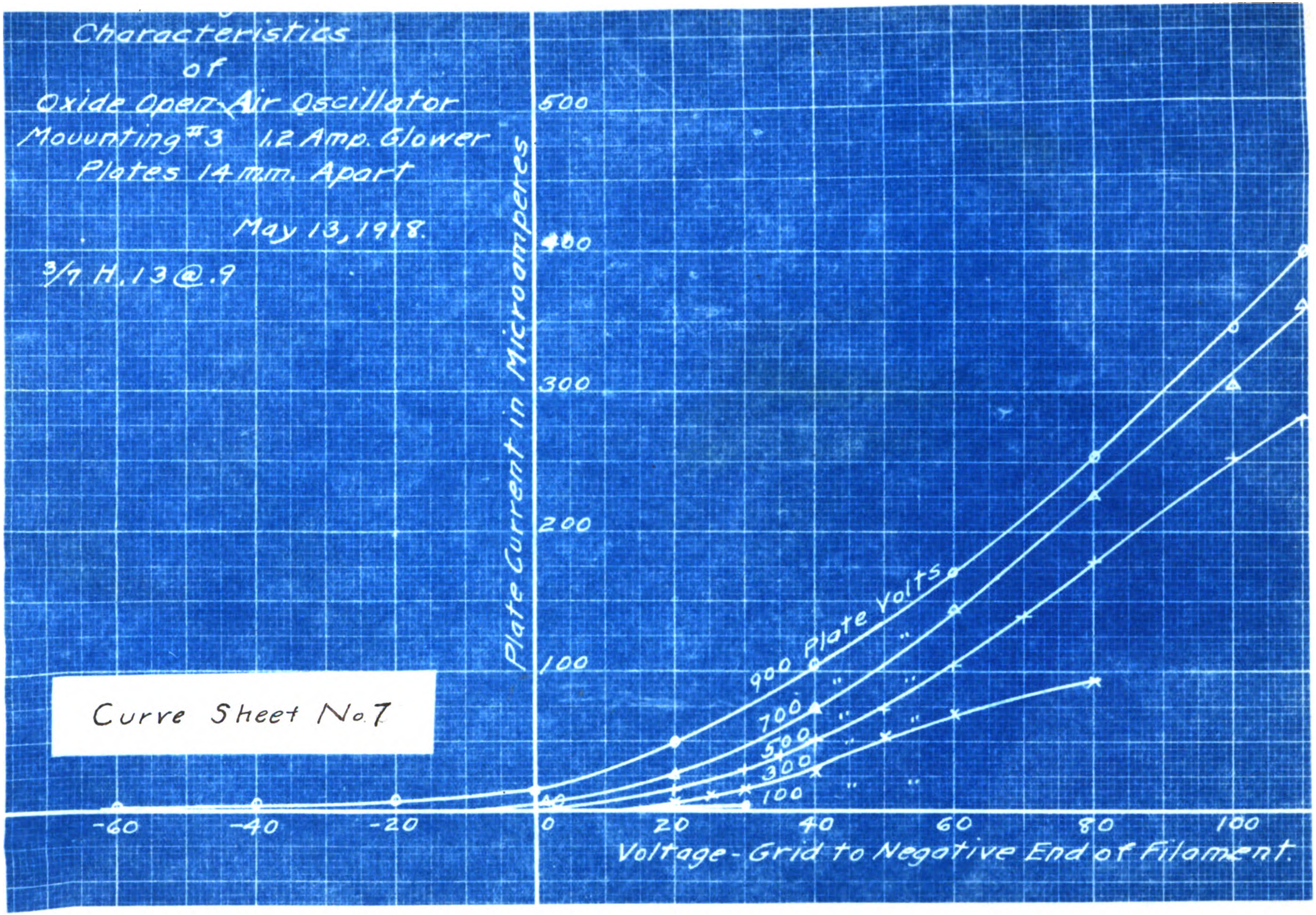
Curve Sheet No. 6.



Characteristics
of
Oxide Open-Air Oscillator
Mounting #3 1.2 Amp. Glower
Plates 14 m.m. Apart.
May 13, 1918.

3/7 H. 13 @ .9

Curve Sheet No. 6.

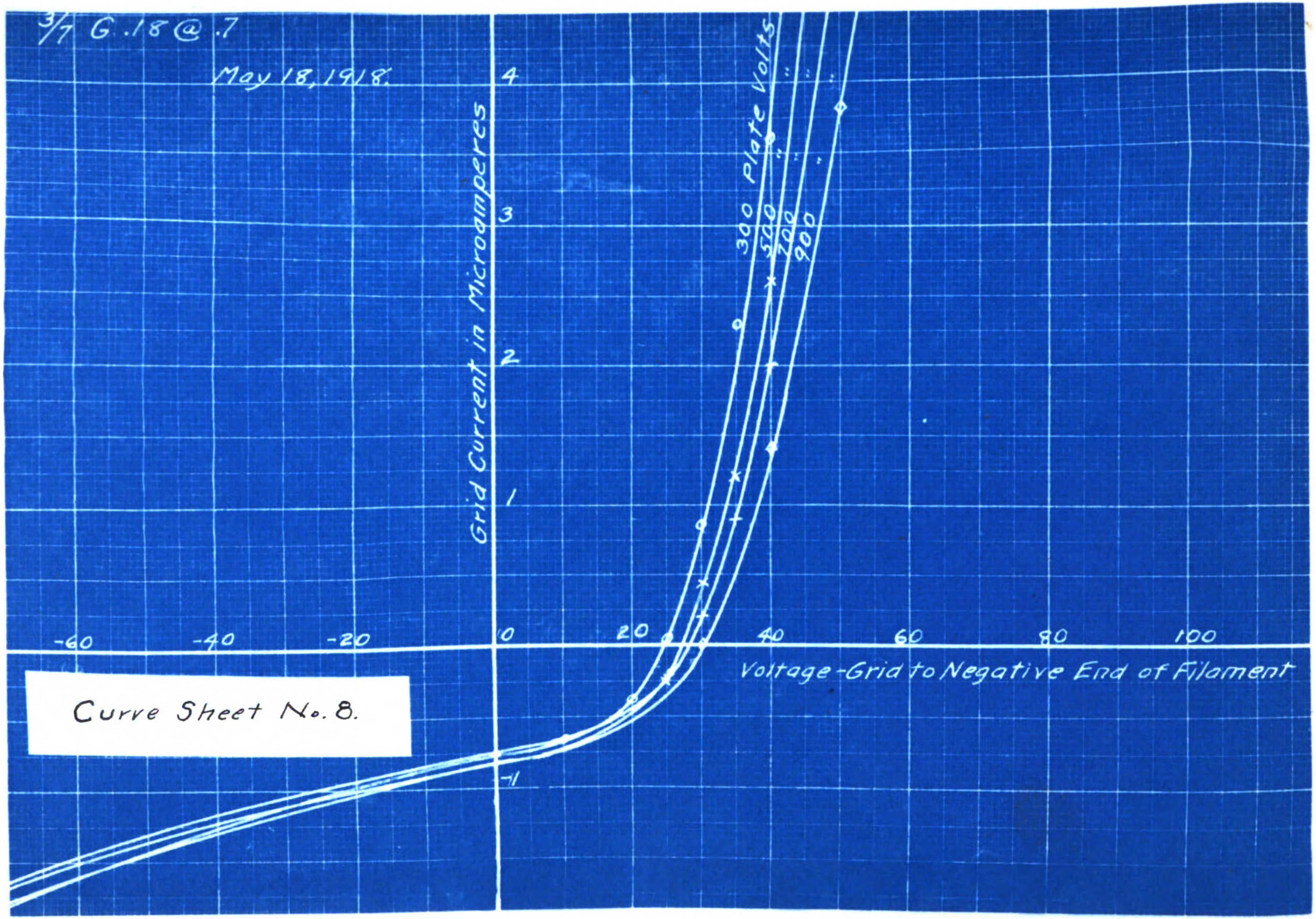


Characteristics
of
Oxide Open-Air Oscillator
Mouunting #3 1.2 Amp. Glower
Plates 14 mm. Apart

May 13, 1918.

3/7 H. 13 @ .9

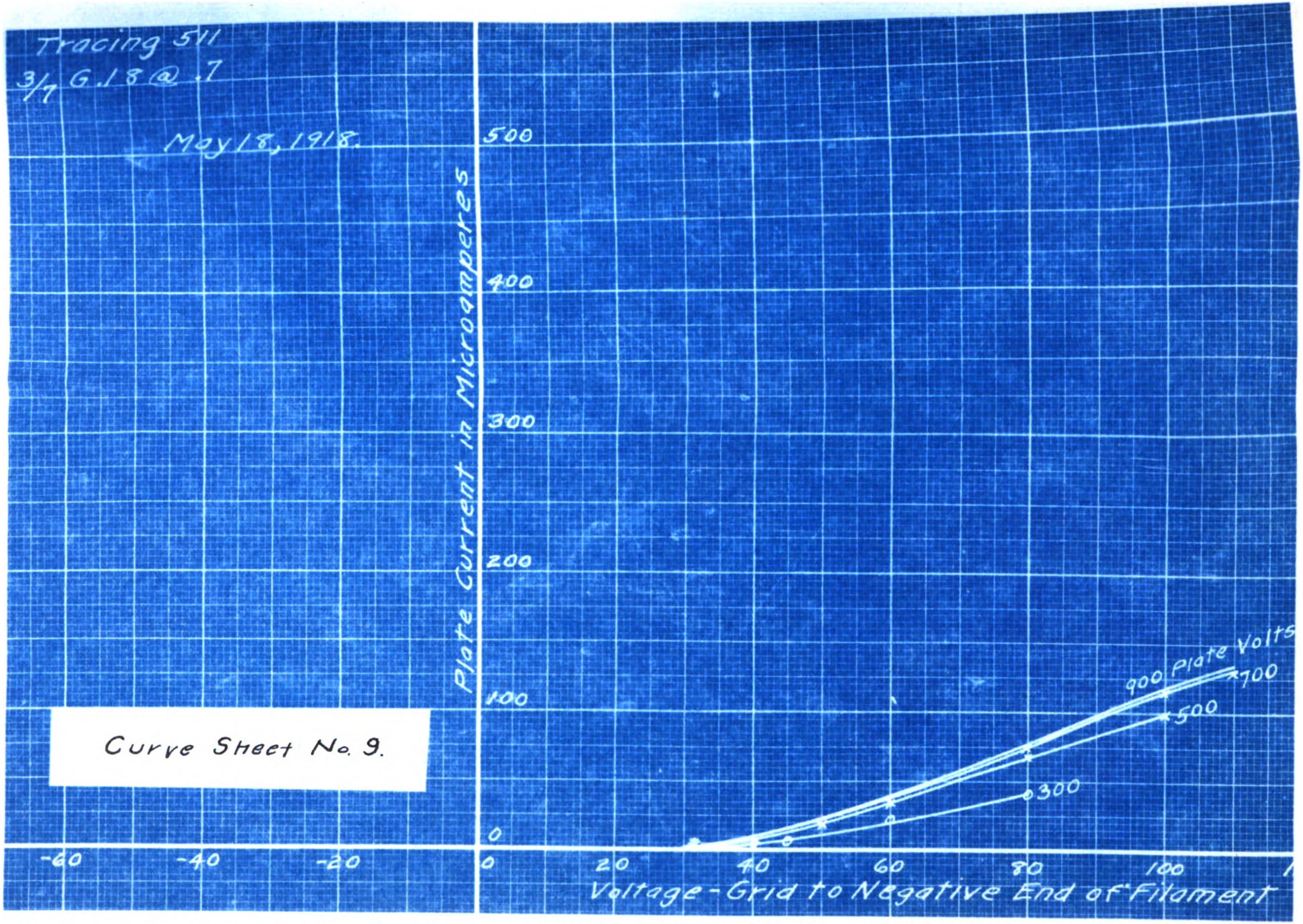
Curve Sheet No. 7



Curve Sheet No. 8.

3/7 G.18 @ .7

May 18, 1918.

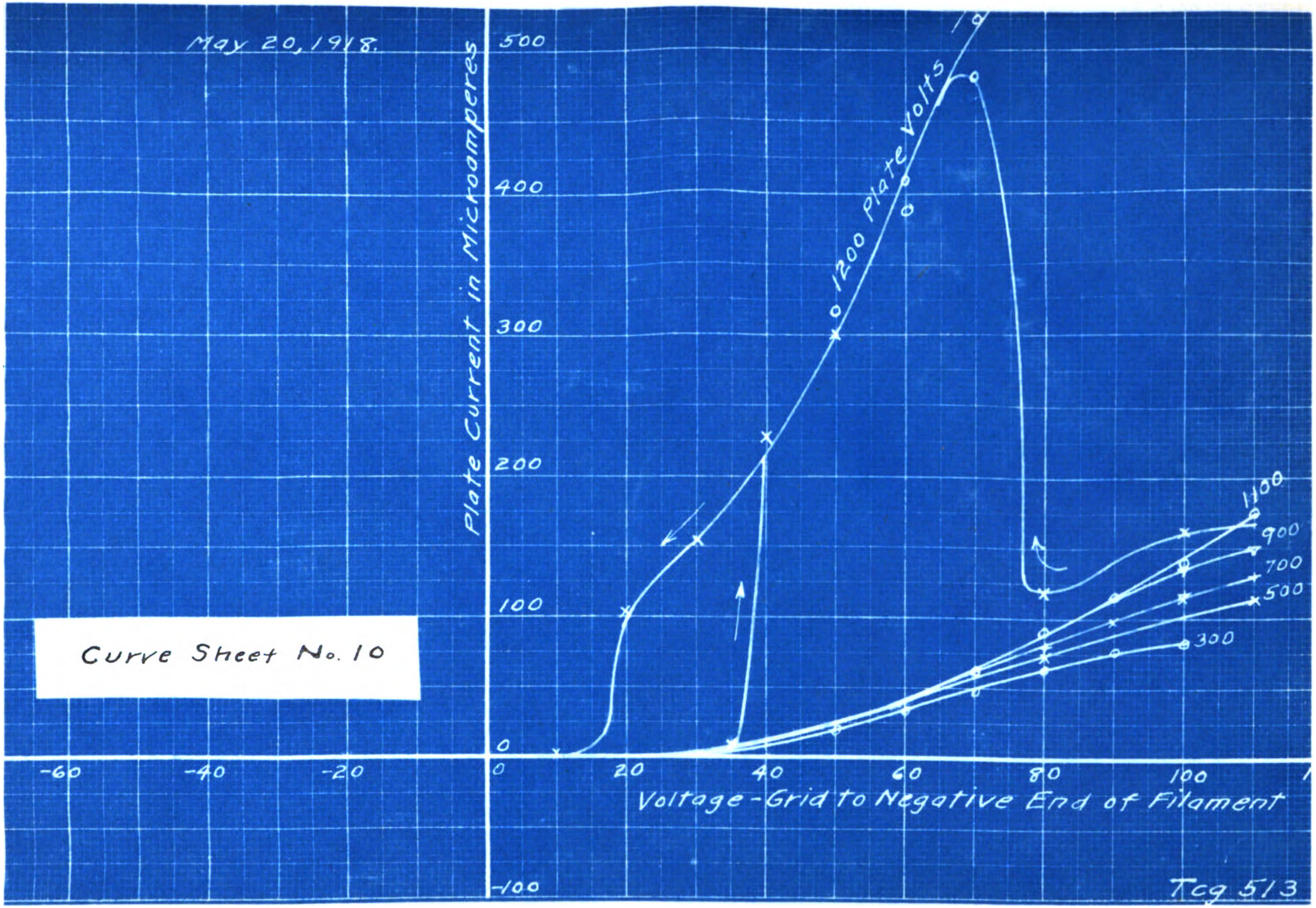


Curve Sheet No. 9.

Tracing 511

3/7 G.18 @ .7

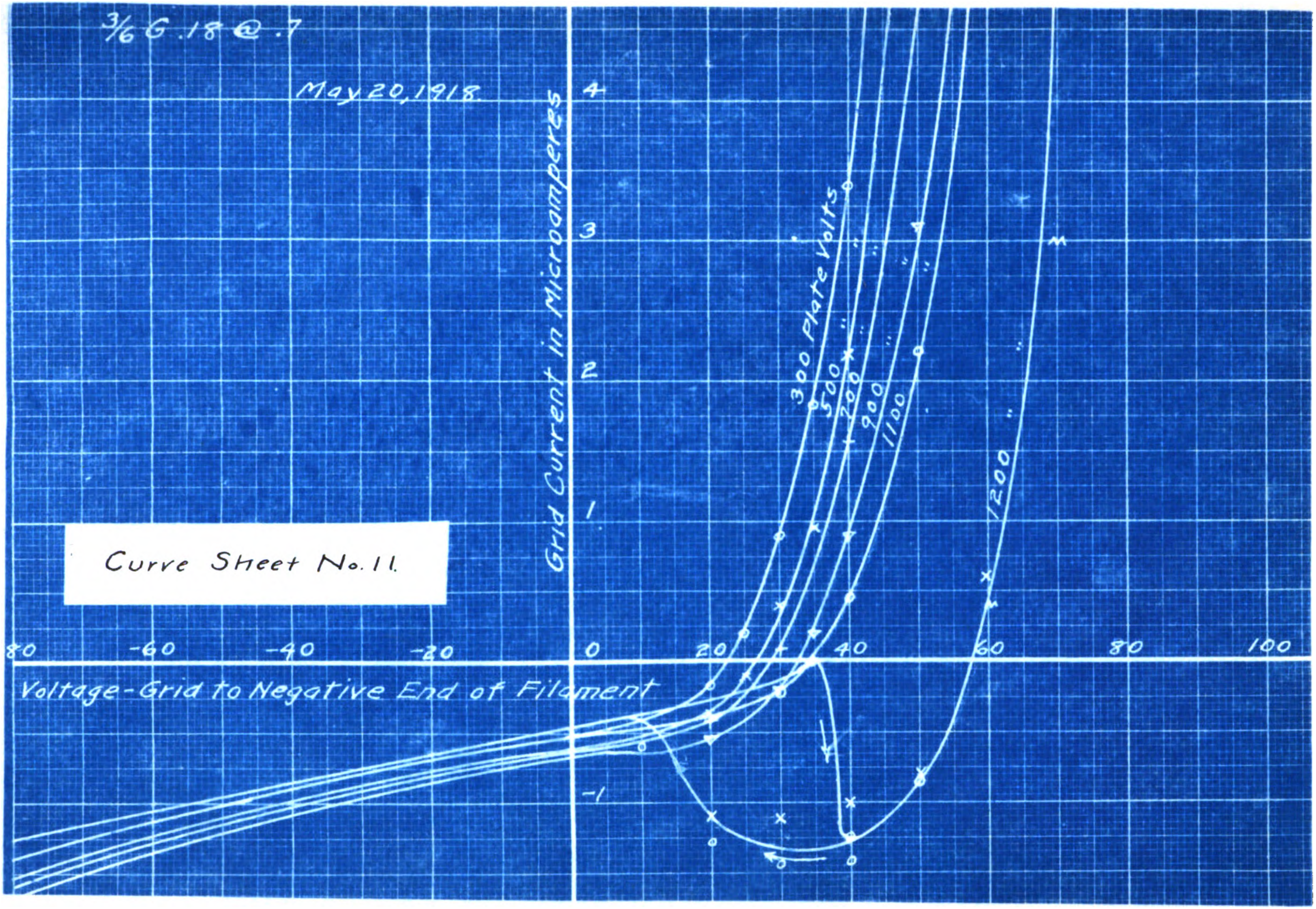
May 18, 1918.



Curve Sheet No. 10

May 20, 1918.

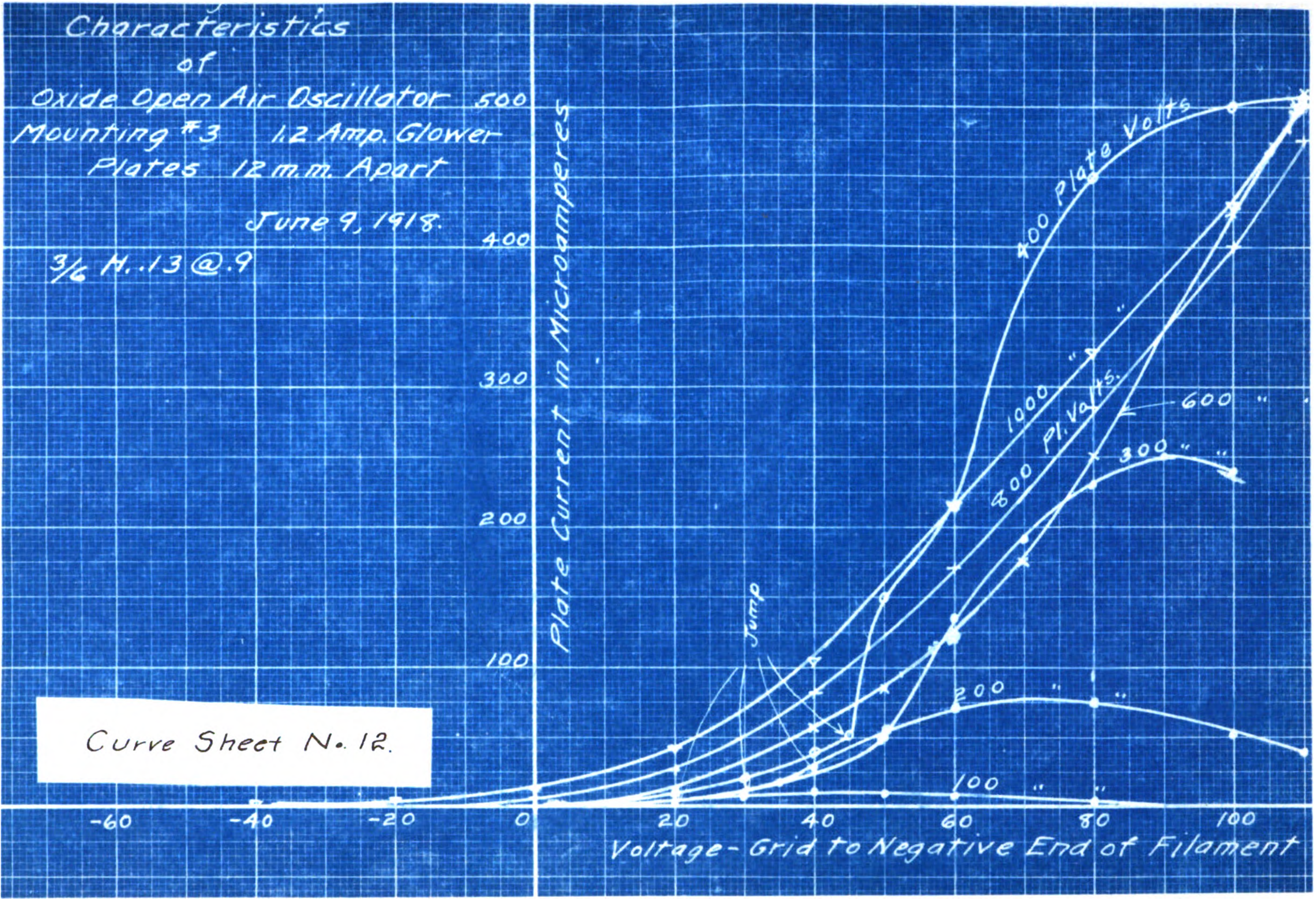
Tcg 513



Curve Sheet No. 11.

3/6 G.18 @ .7

May 20, 1918.

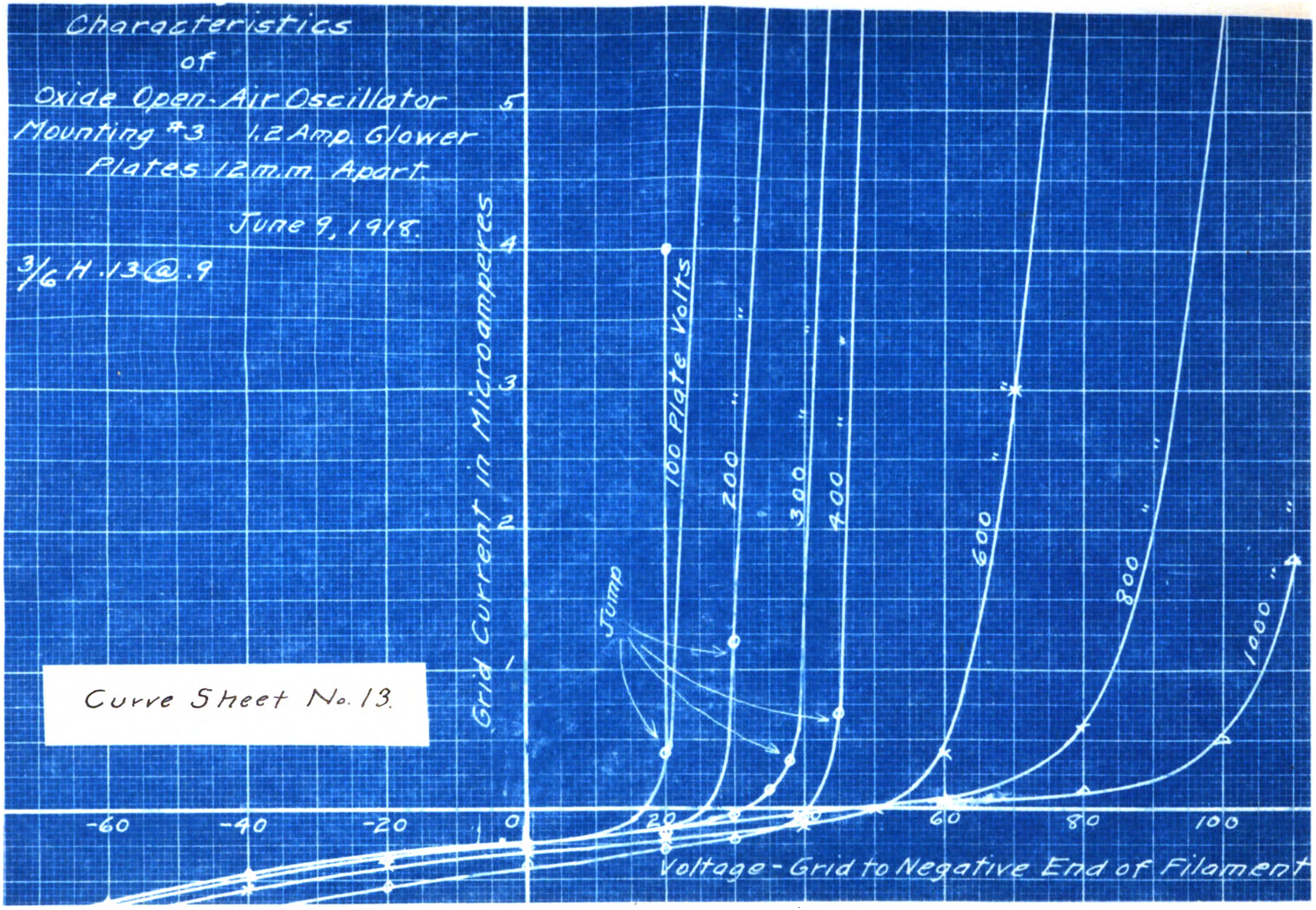


Characteristics
of
Oxide Open Air Oscillator
Mounting #3 1.2 Amp. Glower
Plates 12 m.m. Apart

June 9, 1918.

3/6 H. .13 @ .9

Curve Sheet No. 12.

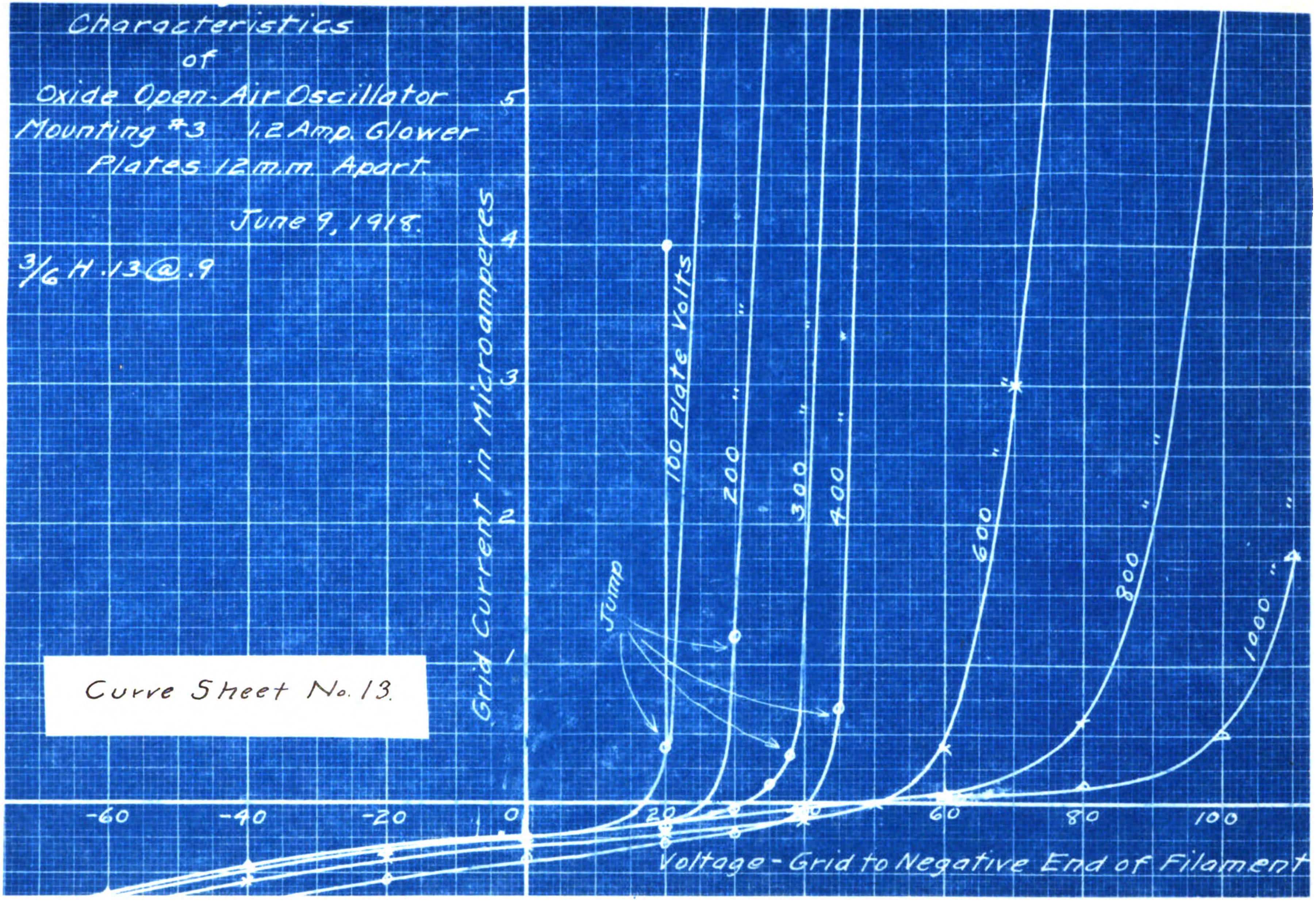


Characteristics
of
Oxide Open-Air Oscillator
Mounting #3 1.2 Amp. Glower
Plates 12 m.m. Apart.

June 9, 1918.

3/6 H .13 @ .9

Curve Sheet No. 13.

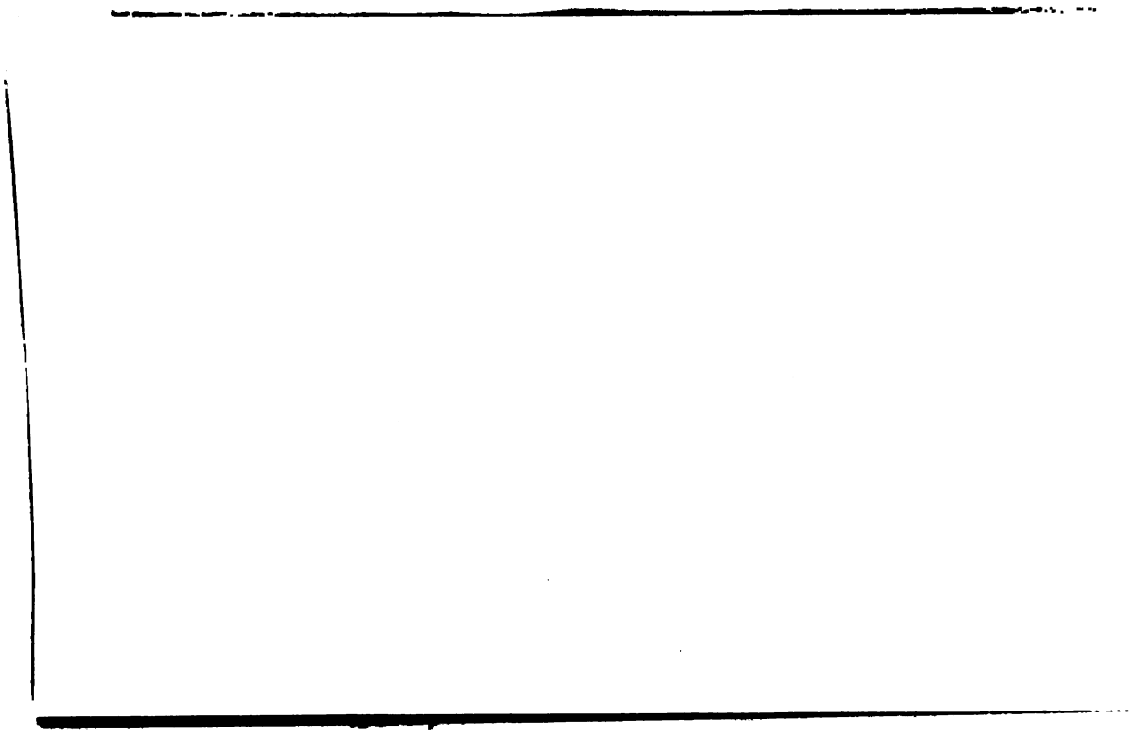


Characteristics
of
Oxide Open-Air Oscillator
Mounting #3 1.2 Amp. Glower
Plates 12 m.m. Apart.

June 9, 1918.

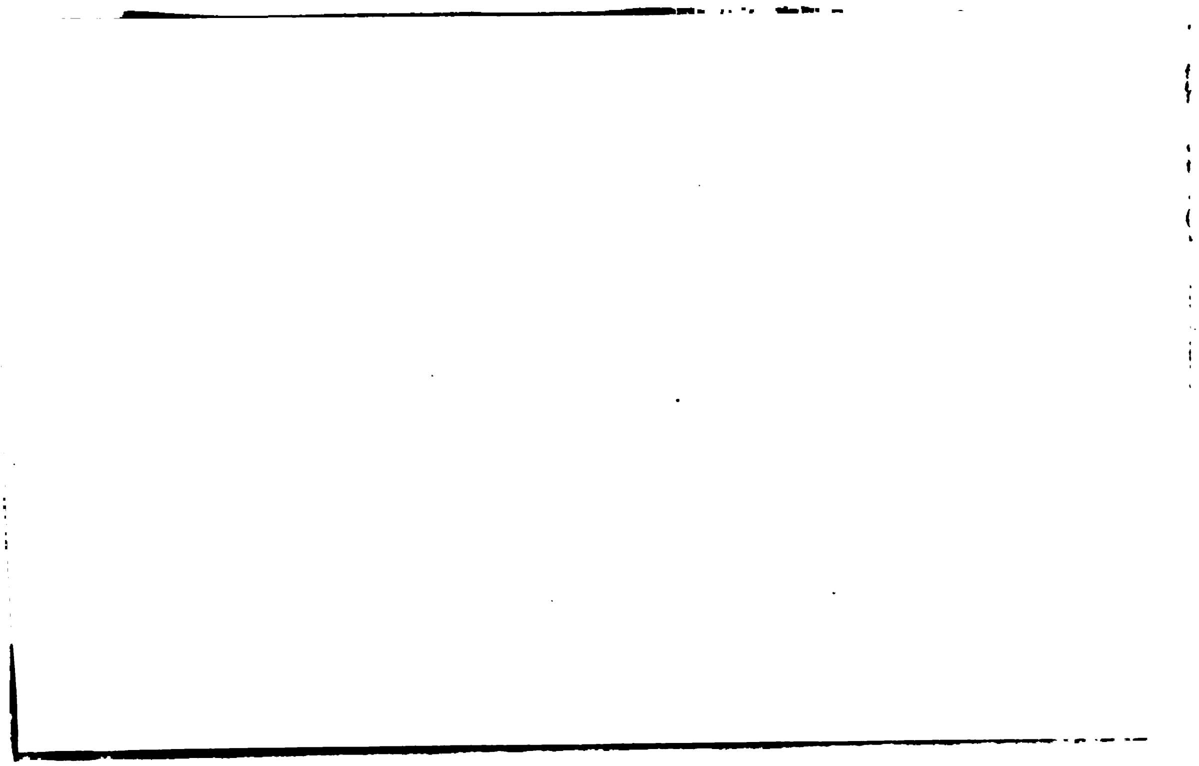
3/6 H. 13 @ .9

Curve Sheet No. 13.



OSCILLIGRAM NO.1.

Plate Current	D.C.-----------------	192	microamperes.
Grid Current	D.C.-----------------	45	"
Plate Voltage	D.C.-----------------	900	volts.
Grid Voltage	D.C.-----------------	80	"
Grid Voltage	A.C.-----------------	31	"



OSCILLIGRAM NO.2.

Plate Current D.C.---------------192 microamperes.

Grid Current D.C.---------------135 "

Plate Voltage D.C.---------------600 volts.

Grid Voltage D.C.--------------- 80 "

Grid Voltage A.C.--------------- 41 "

OSCILLIGRAM NO.3.

Plate Current.

With grid circuit open----------17 microamperes.

" " " closed------ 44 "

Grid Current.

With grid circuit open------- -6.0 microamperes.

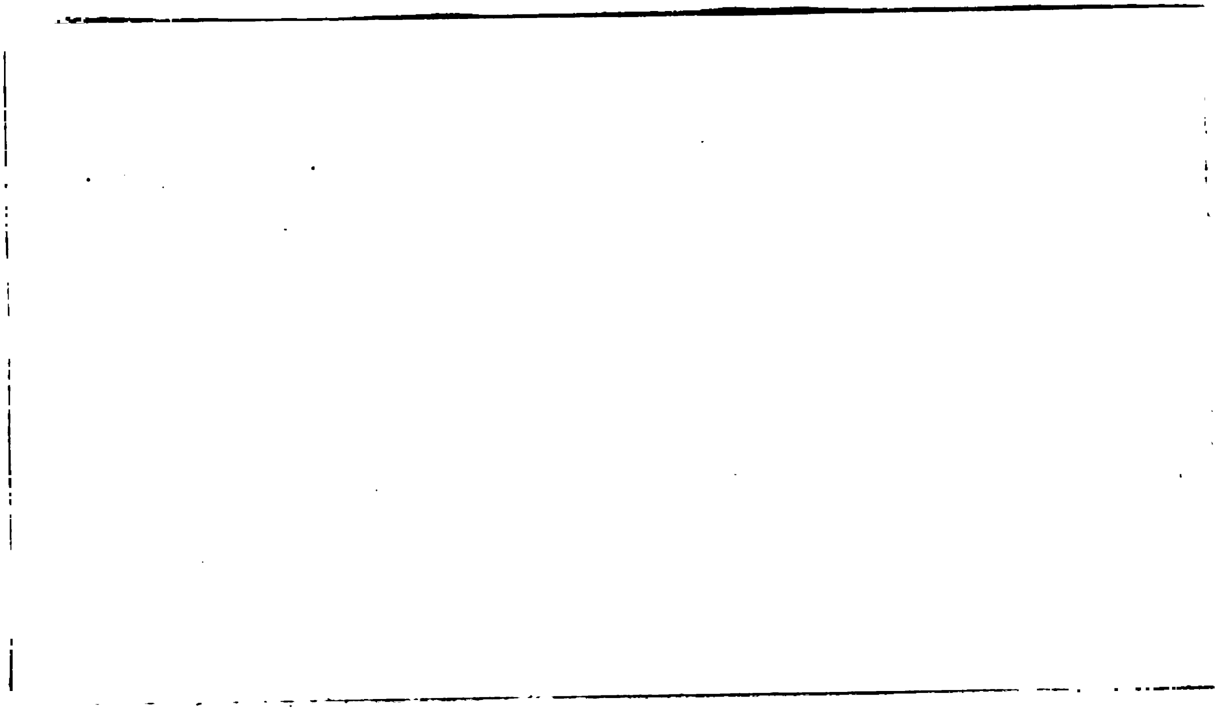
" " " closed---- -4.2 "

(Note that the last two quanties are negative.)

Plate Voltage ----------------- 700 volts.

Grid Voltage D.C.--------- 20 "

Grid Voltage A.C.--------- 41. "



OSCILLOGRAM NO.4.

Plate Current.

Grid circuit open------------------ 45 microamperes.

" " closed---------------- 33 "

Grid Current.

Grid circuit open------------------ 0

Grid " closed ---------------- 0

Plate Voltage D.C.------------------ 400 volts

Grid Voltage D.C.------------------- 42 "

Grid Voltage A.C.------------------- 42.5 "

Stopping condenser in grid circuit.

OSCILLOGRAM NO.5.

Plate Current.

With grid circuit open-------------- 55 microamperes.

" " " closed------------ 68 "

Grid Current.

With grid circuit open-------------0

" " " closed-----------110 microamperes.

Plate voltage D.C.-- -------------- 400 volts.

Grid Voltage D.C.----------------- 42.4."

Grid Voltage A.C.------------------ 42. "

No stopping condenser.

OSCILLIGRAM NO.6.

Plate Current.

Grid circuit open--------------- 125

" " closed------------- Not taken.

Grid Current.

Grid circuit open------------- 0

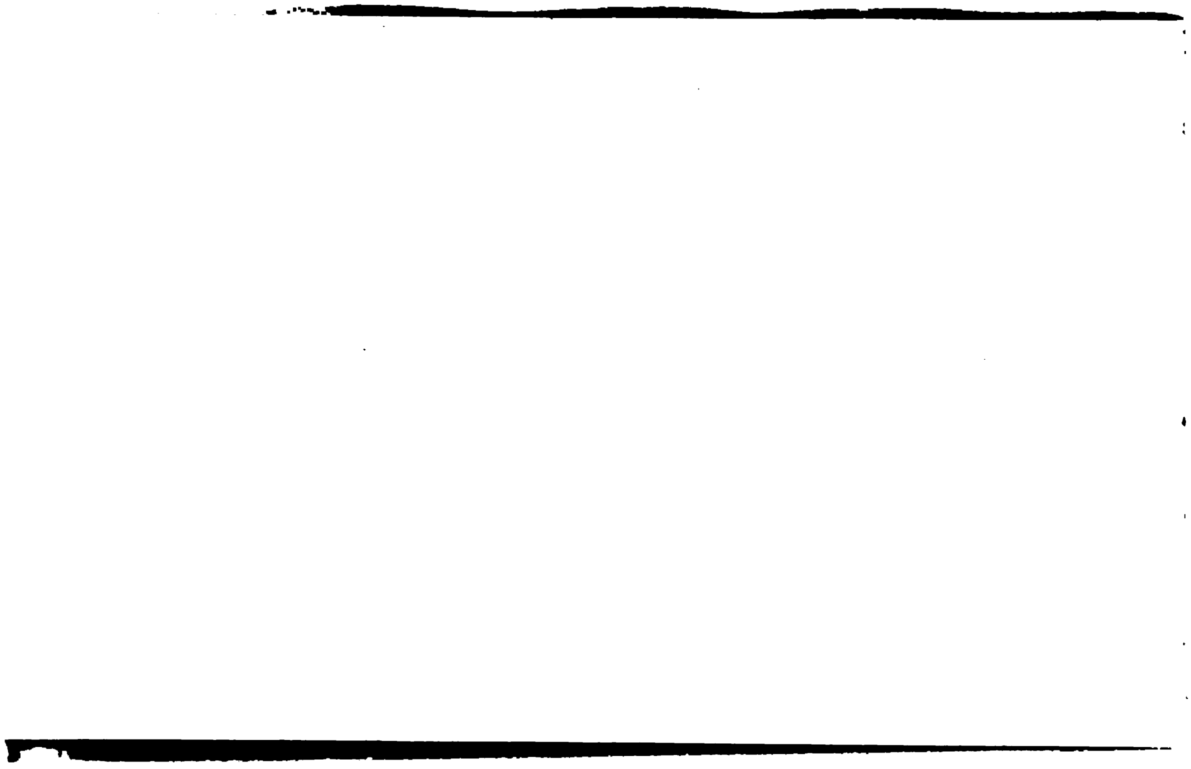
" " closed------------ 0

Plate Voltage D.C.---------------- 600 volts.

Grid Voltage D.C.---------------- 53 "

Grid Voltage A.C. -------------- 42.5

Stopping Condenser in Grid Circuit.



OSCILLOGRAM NO.7.

Plate Current.

Grid circuit open------------------125 microamperes.

" " closed----------------150 "

Grid Current.

Grid circuit open----------------- 0

" " closed----------------- 35 microamperes.

Plate Voltage D.C. ------------------- 600 volts.

Grid Voltage D.C.---------- -------- 53 "

Grid Voltage A.C.------------------- 42. "

No stopping condenser.

CHAPTER III.

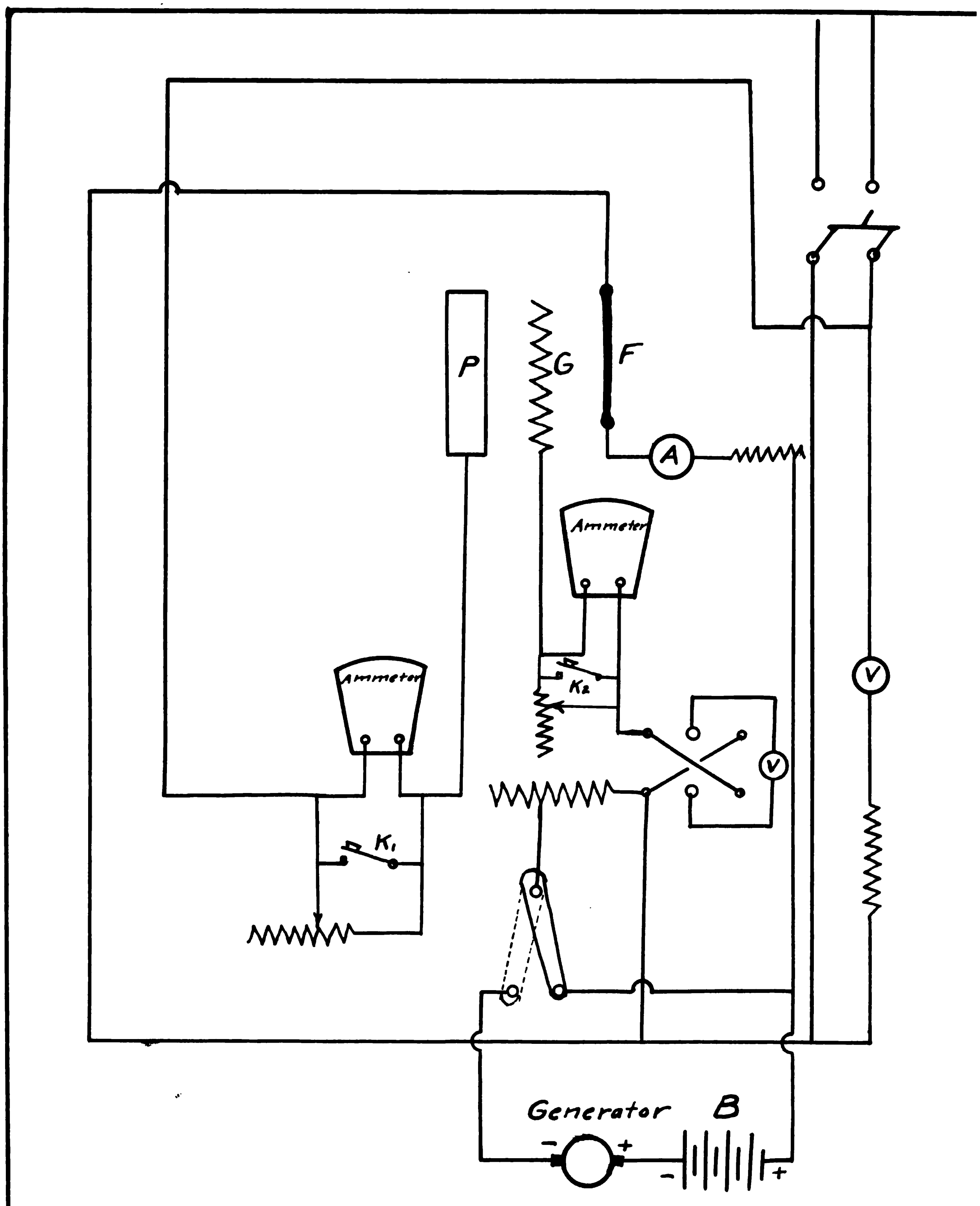
METHOD AND RESULTS.

In the introduction to this thesis, it was stated that the purpose was to determine the conditions and adjustments necessary for the best performance of the open-air device as a detecter.

The experimental work consisted of taking data for characteristic curves, the taking of oscilligrams as a check on the characteristic curves, and of endeavoring to receive from Arlington, Va., with conditions which the curves showed to be most favorable. It was hoped that the characteristic curves would show the best conditions.

The most important part of the experimental work was the taking of data for the characteristic curves, as this offered the only method of attacking the problem in an intelligent manner. While the characteristic curves do not show what conditions are most favorable, they do show some of the unfavorable conditions, and thus a great deal of time ~~is~~ was saved in trying to receive under conditions which cannot possibly give satisfactory results. Besides this benefit, it is only by means of the characteristic curves that the operation of the device can be determined.

For taking the data for the characteristics, the set-up was made as shown in Plate III. For each run, data were taken for two different characteristic curves, one with grid current plotted against grid voltage, and the other with plate current



Set-up for Taking Data for Characteristic Curves.

PLATE III

plotted against grid voltage.

In order to make the explanations better understood and to avoid repetition, these two characteristic curves will be named and hereafter referred to by these names. The curve obtained by plotting grid current against grid voltage will be called "the G-characteristic", and the curve obtained by plotting plate current against grid voltage will be called "the P-characteristic".

The plate voltage was supplied by a generator and the grid voltage and filament current were supplied by a storage battery. Sensative micro-ammeters were used for measuring the plate and grid currents. The filament current was maintained at 1.2 amperes throughout all of the experiments, both in taking data and receiving.

After a set of curves had been plotted, if the conditions looked favorable, the device was connected in the radio circuit and Arlington tuned in. For receiving, the set-up was made as shown in Plate IV. A double throw switch was used so that Arlington could be carefully tuned on the audion, and the audion replaced by the open air detecter by merely throwing the double-throw, three-pole switch. The feed-back Armstrong circuit was used for receiving.

After a considerable number of characteristis curves had been plotted, the most favorable were selected, and oscilligrams taken for the same conditions under which the characteristic curves were taken except that an alternating voltage was impress-

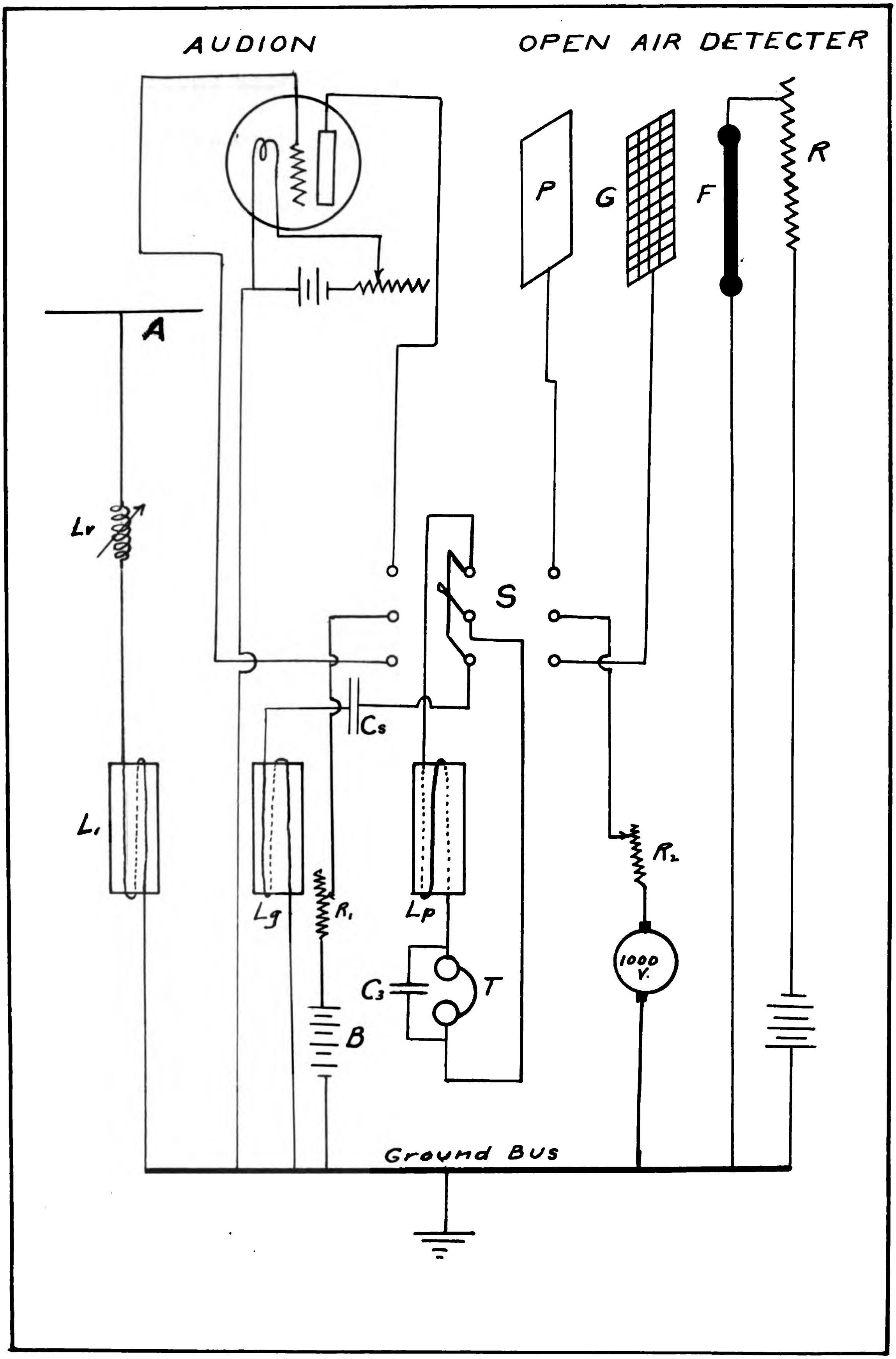

AUDION
OPEN AIR DETECTER
A
P
G
F
R
Lv
S
Cs
L1
Lg
R1
Lp
R2
1000 V.
C3
T
B
Ground Bus

PLATE IV.

ed upon the grid in addition to the direct voltage.

Before discussing the results, an enumeration will be made of the conditions under which the work was done, and the results desired, together with the kind of characteristic curves it is desirable to have in order to get the best results.

There are in general two kinds of grid circuit used for receiving,

1. A grid circuit containing a battery.
2. A grid circuit containing a stopping condenser.

When a battery is used in the grid circuit, receiving is accomplished by means of the rectified plate current, and when a stopping condenser is used, the principal operation is the rectification of the grid current. When a battery is used in the grid circuit, a study of the circuit is made by means of the P characteristic, and the G characteristic is of little consequence. But in studying a grid circuit containing a stopping condenser, both characteristics are of importance.

In this thesis, we are concerned with a grid circuit containing a stopping condenser, and only this method will be considered.

The theory underlying the action of the open air detecter is similar to the theory of the audion, and has already been outlined, but there are many modifications that must be considered, and the characteristic curves are quite different in a good many instances. However, the theory already explained for an audion using a stopping condenser,holds for the open-air detecter, but the effect of grid current has not been explained.

The incoming oscillations are symmetrical with respect to the

zero axis, but the positive half of the wave train does not effect the grid as much as the negative half. This is shown by the shape of the G-characteristic shown in Fig.12. Let the incoming oscillations vary the grid voltage between the positive value OA and the negative value OB, both with respect to the normal grid voltage, or the voltage of the grid when there are no incoming oscillations.

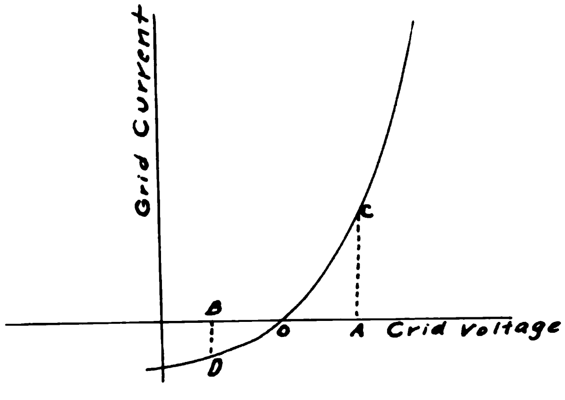


Fig. 12.

When the grid voltage changes from O to OA, the grid current changes from O to AC, and when the grid voltage changes from O to OB, the grid current changes from O to BD. Thus it is seen that the positive half of the wave train causes a much greater surge of grid current than does the negative half. But the time interval is the same for both the positive and negative parts of the wave train, that is, OA = OB in Fig.12. Now, Q = IT, and when T is constant, the greater the value of I, the greater will be the value of Q. It has been shown that the average current is greater on the positive half of the wave train than on the negative half, hence the magnitude of the charge placed on the stopping condenser by the positive half of the wave train is greater than the charge placed on the stopping condenser by the negative half. Now, Q = CE, and the larger the value of Q, the larger the value of E, which shows that the voltage of the stopping condenser is raised to a higher value by the positive half of the wave train than by the negative half.

The plate current is controlled by the grid voltage, and the

rectification of the grid current causes pulses in the plate current of spark frequency.

The above explanation tells us at once what kind of G-characteristic is desired. A large rectifying effect is wanted, and this is obtained where the bend in the curve is most abrupt. The stopping condenser makes the normal grid voltage zero, hence it is necessary that the bend in the G-characteristic occur on the zero axis.

In the discussion of the theory of the audion, it was shown that it is desirable to operate on the steep portion of the P-characteristic, and the same holds for the open-air detecter.

Having determined the kind of characteristics it is desirable to have for the best operation, and knowing that the operation depends upon the characteristics, it is easy to say what the condition ought to be for successful operation. In any circuit, and with constant incoming oscillations, there is a constant variation in the voltage impressed upon the grid circuit. Then if the conditions are such that the G-characteristic has its greatest bend on the zero axis, and the P-characteristic is steep at the value of grid voltage where the grid current is zero, we have desirable operating conditions.

It is seldom that the conditions are such that the best parts of both characteristics can be utilized, and a compromise must be made between the two. If a point can be found where the G-characteristic has considerable curvature, and the corresponding point on the P-characteristic is fairly steep, results can be expected proportional to the respective curvature and steepness,

and for a set of curves taken under varying conditions, one must be chosen which seems to fulfill the conditions best.

Oscilligrams were taken as a check on the characteristics, and show about the same things that the characteristics show. Oscilligram Nos.1 and 2 were taken with connections as shown in Fig.13. The synchronous switch was placed in the plate circuit so that the plate circuit closed when the grid voltage was on the zero point of the wave.

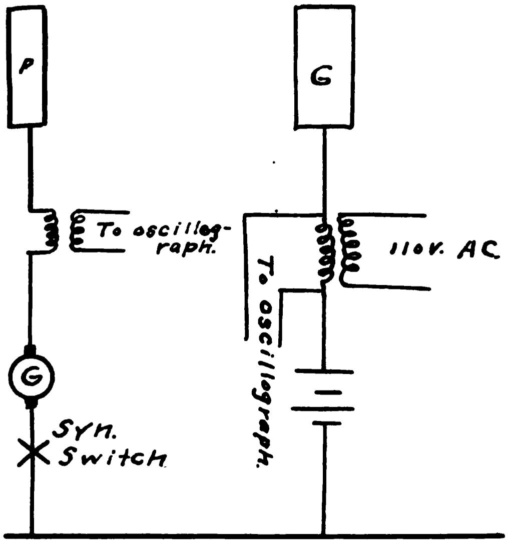


Fig. 13

Oscilligrams Nos.3,4,5, 6,and 7, were taken with the synchronous switch in the grid circuit so that the grid circuit closed when the grid voltage was on the zero point of the wave. The set up was as shown in Fig.14.

Remembering the conditions that must be fulfilled for satisfactory operation, the characteristic curves will now be discussed.

In Curve Sheets 4 and 5 are shown characteristic curves for a plate spacing of 14 millimeters, but with only half as many grid wires as the arbors will accommodate, that is, the grid wire was wound in every alternate groove. Only two of the curves can be considered, as the rest are far removed from the conditions necessary for successful operation. For 300 plate volts, the

bend in the G-characteristic is on the zero axis, and the G-characteristic is very favorable. But the P-characteristic is not very steep at this point. However, the P-characteristic has considerable slope, and the set of curves looks fairly favorable. The 500-volt curves are also fairly favorable,but not as favorable as the 300-volt curves.

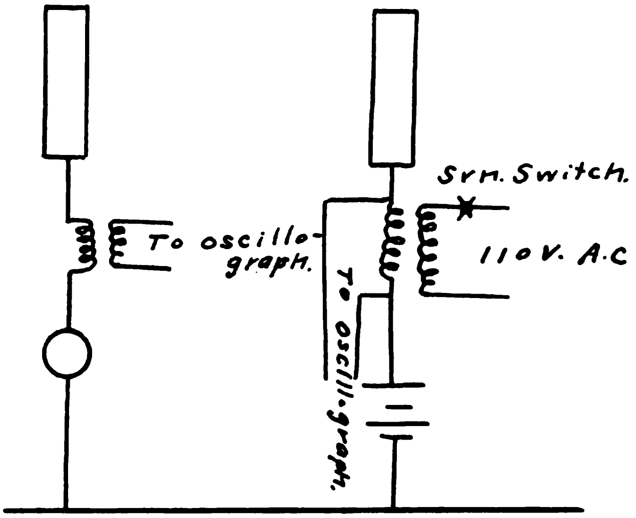


Fig. 14.

Curve Sheets 6 and 7 show curves that are not at all satisfactory and will not be considered, further than to show why they are unsatisfactory. The P-characteristic is favorable, but the G-characteristic is very unfavorable. At points where the P-characteristic is steep, the bend in the G-characteristic is not on the zero axis.

Curve Sheets 8 and 9 are more unsatisfactory than the preceeding ones,and for the same reasons.

Curve Sheets 10 and 11 show curves that are not very stable. The 1200-volt curves would be satisfactory if it were not for the fact that the plate robs the grid of its current.

In Curve Sheets 12 and 13, are shown curves that are unstable. There are points where the currents in both plate and grid jump to high values for small changes in grid voltage. The only favorable curves here are the 300-volt curves, the G-character-

istic being satisfactory, but the plate current only moderetely steep.

Oscilligrams Nos. 2,3,and 7 are the only ones that show very much rectification of plate current. The result shown in Nos. 2 and 3 is to be expected, as the conditions are the same as those giving the steepest characteristic curves.

Oscilligram No.7 shows the effect of using a stopping condenser. There is considerable rectification of the plate current, but the magnitude of the current is small.

Several attempts were made to receive Arlington on the open-air detecter, most of which were unsuccessful. One great difficulty was static interference. On nearly every occasion static could be heard on the open air detecter, but not Arlington.

On one occasion,however, the results were very satisfactory and Arlington could be heard distinctly enough to be read. On this occasion, the conditions were as follows:

Plate spacing = 14 millimeters.
Grid wires per centimeter. = 9.
Plate voltage = 100 to 1000 volts.

The evening was very favorable, and there was very little static interference. The circuit was first tuned with the audion, and the signals were very loud and distinct.

Arlington could be read on the open air detecter with plate voltages varying from 300 to 1000, and could be heard but not read at voltages between 100 and 300. Below 100 volts,nothing could be heard.

CONCLUSIONS.

The work done on this thesis is only a small part of the work that ought to be done to determine whether the open-air detecter is a feasable device. No elaborate calculations were entered into, and the effect of stepping up the voltage of the incoming oscillations was tried out but once, and the possibilities here are not known.

The fact that Arlington could be received distinctly enough to be read, and considering the small amount of work done, seems to indicate that the device possesses merit, and that it is possible to develop it into an efficient detecter.

APPROVAL SHEET.

APPROVED.

The foregoing thesis is hereby approved as a creditable study of an engineering subject, carried out and presented in a manner sufficiently satisfactory to warrant its acceptance as a prerequisite to the degree for which it has been submitted. It is to be understood that by this approval, the undersigned does not necessarily endorse or approve any statement made, opinions expressed or conclusions drawn therein, but approves the thesis only for the purpose for which it is submitted.

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(Title) Professor of Electrical Engineering

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